Implementing the Inventor Robotics and Tablet Robotics in Primary School: The Case Study of Guise Public School

In this report, we recount the learning journey of Guise Public School as they embark on an exciting adventure with the stem.T4L Inventor Robotics and Tablet Robotics kits.

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EXECUTIVE SUMMARY

Over the course of Term 2, 2022 Year 6 and Year 2 students at Guise Public School engaged in hands-on learning activities utilising the Inventor Robotics and Tablet Robotics. A case study approach was designed specifically to explore the two classroom teachers' teaching strategies and innovative ideas for the adoption of the stem.T4L technology, and to document student engagement and learning gains facilitated by the new technology. The data for this study was derived from classroom observations, pre-post classroom assessments, student and teacher reflective journals, and a final teacher interview.

Year 6 received multi-layered lessons on Digital Technologies and were able to produce three artefacts: (1) a matter wand using Micro:bit; (2) a Dashbot zoo; and (3) an interactive poster with Makey Makey. Year 2 students worked with the Dash robot and Blue-bot to practice maths and literacy concepts like addition and subtraction, sequencing, and estimating/measuring length. In working with STEM technology both Year 6 and Year 2 encountered challenges, such as Micro:bit being stuck on a code, Makey Makey not being able to read the correct paragraphs due to wrong wiring, and Blue-bot robots landing on wrong spots because of incorrect programming. Despite the initial struggles, students persisted throughout the activities, employing problem-solving, trial and error strategies and team work.

This report lends valuable insights as to how the two classroom teachers utilised the stem.T4L technology in a primary school setting and what outcomes were achieved. The key findings of this research include:

1. Modest progress was observed in the number of Year 6 students moving from C (Working towards) to B (Working at) or from B to A (Working beyond) categories across the five indicators of Science. The most substantial gain was recorded for the indicator 4 (present data as evidence in developing explanations), where only 2 students remained at C from an initial 10 students. Mr Sapsed attributed this gain to a heightened understanding of algorithms facilitated through the many opportunities students had to use "evidence", and "adjust", and "describe" their code.

2. Students' reflective journals further revealed gains in content knowledge; both procedural (i.e. know-how), as well as functional (i.e. the ability to transfer new learning to other situations). For example, in their reflective journals, some students wondered about the applicability of Dash for helping "blind people" find their way, or using Micro:bit to teach younger students how to spell words, displaying basic level of functional knowledge.

3. A comparison between stem.T4L-enriched environment vs non-technology classroom revealed marked differences. It was found that although a non-tech activity was likely to generate engagement and teamwork/collaboration (behavioural outcomes), technology-integrated lessons tapped into technical (e.g. ICT skills); intellectual (e.g. problem-solving abilities); and social (e.g. interpersonal relationship) domains more prominently. In his journal on a non-tech lesson, Mr Sapsed highlighted two outcomes categorised into behavioural and leadership skills. However, in his lesson on Dash robot he felt like "*all those outcomes [i.e. behavioural, technical, intellectual, social, leadership] were achieved/touched on*".

4. Similarly, not only did Ms Wang observe higher level of engagement when the stem.T4L kits were present, but more willingness on the part of students to help and share ideas, as indicated in her commentary: "*When someone is putting the code incorrectly, another could be like 'oh you have to do this, you have to do that'. Whereas without the kits they're all a bit shy. No one's really putting up their hands to have a go*".

5. Students' rating of classroom experiences with and without the kits suggested a definite preference and affinity for the technology. Year 6's rating of the STEM technology-integrated lessons was averaged at 9.07. However, a rating of 6.61 for the non-technology lesson indicated that the activity was less popular and not immediately appealing to students, highlighting the potential of the stem.T4L technology to create a fun and engaging learning environment.

6. Mr Sapsed applied an "I do, you do" approach when teaching with STEM equipment, signifying the centrality of scaffolding and modelling the tasks, especially for students from low socio-economic status with no prior exposure to technology. Ms Wang also viewed a step by step approach the most effective tactic when introducing new technology.

7. The "I do, you do" approach consisted of key stages. During the "I do" phase Mr Sapsed would go through a process of explaining, demonstrating, challenging, observing, supporting, and providing feedback. In the "you do" phase students would wonder, investigate, refine, modify, share and reflect on their learning.

8. A discussion with the two teachers on the constraints and limitations of integrating the equipment revealed that time pressures could preclude teachers from exploring the affordances and the applicability of the equipment to meaningfully integrate it into their lessons. Also, what acts as another deterrent is some teachers' lack of experience and low confidence in using technology, according to the teachers.

INTRODUCTION

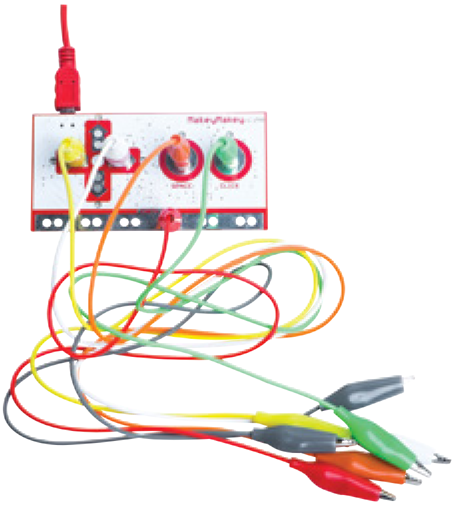
In this report, we recount the learning journey of Guise Public School as they embark on an exciting adventure with the stem.T4L Inventor Robotics and Tablet Robotics kits. The aim of the study is to draw upon teachers' classroom experiences of integrating the stem.T4L equipment into their teaching to answer the following questions:

1. What innovative ideas teachers have for the effective implementation of the Inventor Robotics and Tablet Robotics in a Primary school setting?
2. What learning outcomes do they help students achieve?
3. What pedagogical strategies facilitate the use of the kits?
4. What affordances and constraints do the STEM kits have?

The two classroom teachers participating in this study, Mr Sapsed and Ms Wang[1], designed and orchestrated the learning activities for their Year 6 and Year 2 students, respectively in Term 2, 2022. Mr Sapsed implemented the Inventor Robotics—one of the eight of the stem.T4L kits that comprises of LEGO Spike Prime x 12; Makey Makey x 12, Micro:bit x 12; and laptops x 12. Ms Wang had the Tablet Robotics kit, which includes Dash Robots x 10; LEGO WeDO 2.0 x 10; Blue-Bot x 12; and iPad x 20. Before diving into the details, we present a brief overview on the features and affordances of the robotic tools implemented for the purpose of this study (i.e. Makey Makey, Micro:bit, Dash Robots, & Blue-Bot[2]).

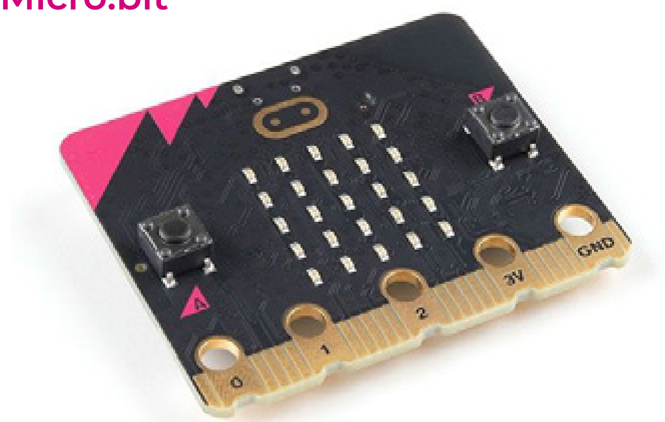
[1] *Both classroom teachers consented to be named in the research paper.*
[2] *Please note other components of the kits such as the Spike Prime and the LEGO WeDo were not used by the classroom teachers.*

Makey Makey



Makey Makey is a simple device, consisting of a circuit board, crocodile clips, and a USB cord, and is used widely as a teaching aid in Primary schools. This invention kit transforms any material that is conductive into a physical interface for any software, allowing learners to understand abstract concepts even in maths or science (Collective & Shaw, 2012; Manches et al., 2010). As the Makey Makey opens up the possibility for connecting different physical and everyday elements to this device, it promotes learners' interaction with the environment, cultivating their computational thinking and creativity (Morais & Bachrach, 2019). Previous studies also suggest that the implementation of the Makey Makey can improve knowledge and skills acquisition, motivation, and engagement, to name a few (Fokides & Papoutsi, 2020; Johnson et al., 2016).

Micro:bit



Micro:bit is another physical device used for teaching coding as well as supporting students' STEM learning. It consists of an LED light display, buttons, and sensors, which makes it an easy, fun, and engaging way to practice programming (Kalelioglu1 & Sentence, 2020).

Dash Robot

Dash, coming as a pre-assembled robot, is another coding platform that connects to a device via Bluetooth. With wheels under each side, Dash has the ability to spin and move around. The head component is mobile too and it contains an eye with LED lights and can be coded to flicker or make noises[3].

Blue-Bot

Blue-bot is another Bluetooth robot that can connect to a tablet remotely and perform the program created on screen or on the robot itself. It has a clear shell and has the capability to perform 45 degree and 90 degree turns— ideal for drawing different shapes.

[3] *Further information on Dashbot is available at* https://smarterlearningguide.com/dash-and-dot-robot-review/

METHODOLOGY

Context of the study

After the completion of an in-depth case study on Secondary school students[4], this time the stem.T4L research team designed a case study for Primary students, with all schools with a booking for stem.T4L kits eligible to participate. However, unique challenges of the Covid era, took a toll on school engagement in research. Although there was an initial positive uptake, most of the schools that had volunteered to participate pulled out eventually due to unforeseen circumstances (e.g. staffing issues, transitioning to a new role, changes in school timetable, etc.).

Guise PS, that had the Inventor Robotics and Tablet Robotics booked for Term 2, 2022, remained a willing volunteer. Located in the south-west of Sydney, Guise PS is a beautiful school with slightly over 200 students, 30% of which identify as Aboriginal and 36% are from a language background other than English. The school places a strong focus on professional learning and advocates for the development of evidence-based programs through collaboration and mentoring[5]. A real affinity for educational technology is also displayed at the school evident in their ownership of some STEM technology (e.g. Bee-bots, Lego Wedo, Spheros, Ozobots, Makey Makeys), or their bookings of the stem.T4L equipment and resources. Students' sound understanding of the STEM technology and their sustained engagement and interest in technology-assisted activities, as observed throughout the course of the study, are also strong indications that a positive attitude towards technology is cultivated by the school, and technology is embedded in the classrooms.

Participants

The Year 6 class, comprising of 27 students, 14 females and 13 males, worked with Makey Makey, Micro:bit, and Dash Robot to complete a number of projects, as will be explained in the following sections. The Year 2 class included 22 students, 10 females and 12 male and used Dashbot and Blue-bot to learn about maths and literacy concepts and skills. The two classes met every Wednesday in Term 2, 2022 for an hour and received technology-integrated lessons designed by their teacher.

Mr Sapsed and Ms Wang, teaching Year 6 and Year 2 respectively, volunteered to participate in the study. Mr Sapsed, having seven years of teaching experience, is passionate about technology and has been always keen to see how he can harness and integrate it into his teaching, as he finds it "a lot easier to engage kids and get them to learn through technology". Being surrounded by technology as a child, and born into a family "very much into tech", Mr Sapsed feels comfortable and confident with using educational technology in the classroom. He strongly believes that the teacher role has evolved into being a "preparer", and as part of that he needs to prepare his students for the challenges of the new digital world and make sure "they are able to function in society".

Ms Wang started teaching in 2020, and although she is "kind of confident" using technology, she thinks embedding it in the classroom "is sometimes where it gets a little bit tricky", making her wonder "how can we slot that [technology] in there?". But what motivates her to keep trying is that instant excitement and higher level of engagement in students whenever she brings out the technology. In addition, Ms Wang attests to the importance of integrating technology because she believes that students who are tech savvy "become future-focused" as well as "creative, critical thinkers and problem solvers", hence ready for "the changing nature of the future jobs opportunities that will be out there for them".

Data sources

Classroom observations:

Data collection recurred continually over Term 2, and different data sources were tapped into to enrich our understanding of the dynamics of classroom experiences shaped by the stem.T4L kits. Non-participant observations were scheduled in consultation with the teachers, and in total three

[4] *IVR as a tool to create digital art: The case study of Blacktown Girls High School's engagement with stem.T4L available at:* https://schoolsnsw.sharepoint.com/sites/STEMShareLibrary/SitePages/Research-and-Evaluation.aspx

[5] *The information on Guise PS is retrieved from* https://reports.sparo.schools.nsw.gov.au/plan-report/2021/4461/2021-2024_Guise_Public_School_SIP.pdf

observations were conducted. During each classroom observation, the researcher, staying separate from the activities, took notes, pictures[6], and videos of students' reactions and behaviour regulated by the presence of the kits in the classroom. To streamline the note-taking process, pre-defined behavioural categories were defined in the format of an observation rubric, where examples of actions and behaviour (e.g., on/off tasks behaviour; challenges of working with the kit; skills/competencies displayed when working with the technology; general atmosphere of the class, etc.) were recorded manually. Another purpose of the observations was to document teachers' approaches and techniques employed when utilising the technology. The observation notes were later triangulated by the teacher interview data, held at the end of the study, where the teachers dissected the teaching vignettes to reflect and discuss their teaching strategies.

To minimise the time demands on the Year 2 teacher, research activities were confined to three classroom observations and a final teacher interview. Additional data, however, was collected from the Year 6 class, including four lesson reflections, two classroom assessments, and students' work samples.

Reflective journals:

Year 6 students and their teacher were invited to reflect on their weekly lessons on the Digital Technology unit and respond to a number of multiple-choice and open-ended items. Some of the lessons were non-technology based, where students used everyday materials to experiment (e.g. Bread, Butter, Vegemite, and Cheese to practice algorithms). The journals collected based on these lessons were compared with those of technology-based activities to examine respondents' feelings and evaluation of their classroom experiences in two different settings: a stem.T4L-enriched environment vs a conventional science classroom.

Assessment rubric:

Another key component of the study was measuring stem.T4L resources for its potential to improve the learning outcomes, as described in the K-6 Science Syllabus. To this end, an assessment rubric was created in liaison with the Year 6 teacher prior to the study. In line with the lesson objectives of the Science (Digital Technologies) unit, the teacher tracked and documented students' progress in four areas, namely:

ST3-2DP-T: Plans and uses materials, tools and equipment to develop solutions for a need or opportunity.

ST3-11DI-T: Explains how digital systems represent data, connect together to form networks and transmit data.

ST3-6MW-S: Explains the effect of heat on the properties and behaviour of materials.

ST3-7MW-T: Explains how the properties of materials determines their use for a range of purposes.

The teacher estimated the proficiency of students against five indicators of the above Syllabus outcomes (e.g. 10 students are 'working towards' proficiency for indicator 1, while 5 are 'working beyond' for the same indicator), at two time points; at the beginning and at the end of Term 2. To examine the extent of progress in the identified outcomes, the before and after assessment rubrics were analysed and later reviewed by the teacher for additional input. The results of this assessment are presented in the Discussion section.

[6] *Consent was sought prior to the data collection to ensure all students had 'permission to publish'. Students who did not have a consent form, were not photographed.*

YEAR 6'S ADVENTURE WITH MICRO:BIT, DASH, AND MAKEY

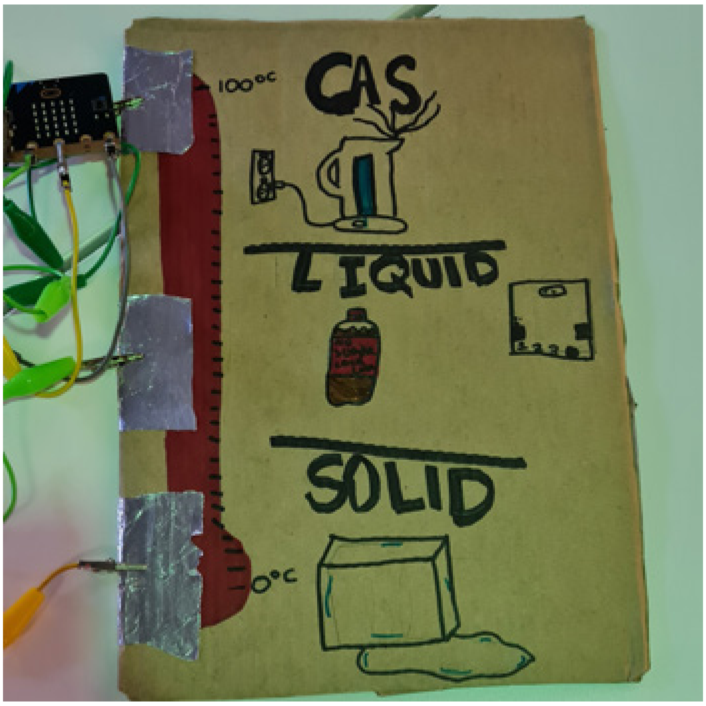
Year 6 students received nine lessons on Digital Technologies, which as Mr Sapsed wrote in his lesson plans, focused on "understanding the role individual components of digital systems play in processing and representing data". Accordingly, the activities designed for this unit intended to promote students' knowledge of "project management, abstraction, and the relationship between models and the real-world systems".

While each lesson had its own objectives and set of activities to be completed by the end of the lesson, some activities were structured sequentially, with an overall theme bundling the lessons up. For instance, as Figure 1 shows, the lesson on Micro:bit included two main components; a non-technology activity, where students created a cardboard display of states of matter in the first lesson, and a technology-integrated exercise, where students used Micro:bit to code their "matter wand", in the second lesson. Given the focus of the study on the integration of the stem.T4L equipment, only lessons that had a technology component were observed. In the following section, the learning activities designed for the Tablet Robotics and the Inventor Robotics are described and accompanied by researcher's notes, pictures, and work samples collated for each lesson.

Year 6	Activity	Resources
Lesson 1: Micro:bit	1: Making a display of the different states of matter of water.	Cardboard Sharpies Foil
	2: Coding Micro:bit to display the 'matter wand'.	Micro:bit Laptop crocodile clips Foil
Lesson 2: Dash Bots	1: Making an algorithm for making sandwiches	Bread Butter Vegemite Cheese
	2: Making an animal from Sydney zoo using the Dash to bring it to life	Dash bots iPads Makerspace materials paper/scissors/sticky tape
Lesson 3: Makey Makey	Using Makey Makey to bring an animal informative text alive	Laptops Makey Makey Photocopies of book

Figure 1. Year 6 lesson plan

Making a matter wand using Micro:bit



Over a two-week period, Year 6 learned and explored the different states of matter (solid, liquid, & gas) with the help of the Micro:bit, which produced a kinaesthetic-tactile and interactive learning experience.

The first lesson was an introduction to states of matter that aimed at creating a cardboard display of the different states. To better understand the activity, students watched a video tutorial that walked them through the step by step procedure (https://makecode.microbit.org/projects/states-of-matter). After that, it was their turn to come up with a design that displayed the three different parts (solid, liquid, gas); the 0 to 100 degrees temperature; and a visual to assist with the headings. Each group of students were provided with a cardboard and sharpies to create their display. But, what functional elements the Micro:bit could add to students' project? So, in the second lesson, which was captured through the classroom observation, students were introduced to the Micro:bit. The vignettes below serve to illustrate how the teacher orchestrated the activities and how the students responded to the tasks.

Observation 1

To kick off the lesson, Mr Sapsed provided students with a broad outline of the lesson, which is creating a "matter wand" using the Micro:bit, and passing on the new-found learning to Year 2 students. Dividing students into several groups, the teacher assigns the first task: "have three bits of foil and attach them to the side of your project". He further explains that students also need crocodile clips and Aluminium foil to create a circuit for the Micro:bit, as "circuits need to be touching metal to be conductive", he adds. The teacher, checking students' understanding of the task enquires: "how many of these [showing a piece of foil] do you need?". Students listening attentively to the teacher reply: "Three". The teacher confirms by adding: "One for liquid, one for solid, and one for gas".

The activity is timed for five minutes and students start cutting and gluing pieces of foil to their cardboard. "But where does the Micro:bit go?", asks one boy with open curiosity. The teacher replies that they need to attach the Micro:bit to the graphics with the crocodile clips but before that they need to code the Micro:bit.

Once all groups are finished with the first task, they watch the same tutorial to see how the Micro:bit reads the information from each state of matter. "But that does not just happen", the teacher reminds the students, "we need to actually put code and algorithm into the Micro:bit using the laptops". Adopting an "I do, you do" approach, the teacher gives students a demonstration of each step they need to take. Students watch Mr Sapsed as he opens the Makecode page on his computer and models the task:

Teacher: "You are going to open up Chrome, and then type in Microsoft Makecode. What are you typing in?"

Students: "Microsoft Makecode"

Teacher: "...and then click on a 'new projects' and name your project 'states of matter' and then click 'create'".

Some level of noise is heard as each group pulls out a laptop and tries to log into their computer; however, they stay on task and show a clear interest in the activity.

Coding starts with a demonstration by the teacher, where he elaborates on the three codes that students need to put into the Micro:bit (0 to say 'gas', 1 to say 'liquid', and 2 to show 'solid'), using the Microsoft Makecode platform. Once he is finished with coding the 0 pin he pauses:

Teacher: "I want to let you do the next one yourself".

The silence in the classroom suggests students are ready to have a go. To guide their way, the teacher prompts students:

Teacher: "We want 1, once pressed, to say liquid; and we want 2, when pressed, to say solid. Can you do that for me guys?".

Students begin coding their Micro:bit with a burst of energy and enthusiasm. They mostly work in groups, except a few students who take over and experiment on their own while their peers watch.

After coding the Micro:bit, the teacher provides a handy tip for testing if the data is stored:

Teacher: "if the red light flashes, that means the data is there".

Students carry on with the tasks: they test their Micro:bit, download the codes, and save them onto their laptop. The final step is to connect the Micro:bit to their projects using four crocodile clips:

Teacher: "The first wire goes from 0 to gas, the second one goes from 1 to liquid, and the third wire goes from 2 to solid. The fourth wire goes from ground, and that is going to be your 'wand', that you guys use to touch and to control. Does that make sense? Any questions?"

There is no question at this stage, but once students start to connect the crocodile clips to test their matter wand, some encounter challenges and some see that it works. As the class continues, joyous shouts of "it is working!" go up:

Student: "Mr! it works!"

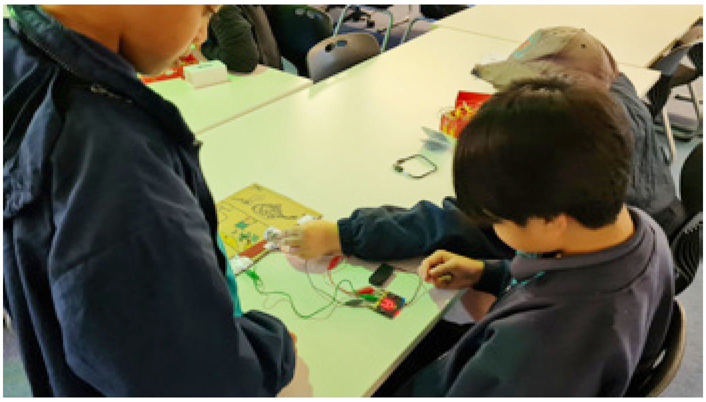
Teacher: "It works? Wonderful! You guys are good".

Student: "This is so much fun".

Snippets of conversation indicate that some groups adopt problem-solving and trial and error approaches, while others seek teacher's support when confronted by technical challenges. For instance, a group consisting of two girls, who kept working together harmoniously, struggle with their wand as the Micro:bit keeps showing 'solid' when the wand touches different states. They rearrange the order of the wires to see if there is any change. They also make sure the wires are firmly attached to the pieces of foil but the wand appears to be stuck on 'solid'. They finally decide to get help. Mr Sapsed assessing the Micro:bit suggests to reset the Micro:bit:

Teacher: "You need to reset the Micro:bit, you do that by just taking off the battery pack lid, just lifting the battery out, turn it off, put the battery back in, and that will reset the Micro:bit so that your wand is working".

In another group, the Micro:bit does not read the right state. For example, when the wand touches 'gas', it reads it as 'liquid'. Students determined to find out why, keep trying out ideas until they realise they have connected the crocodile clips to the wrong states. The following pictures show students in different groups performing a final test on their matter wand.

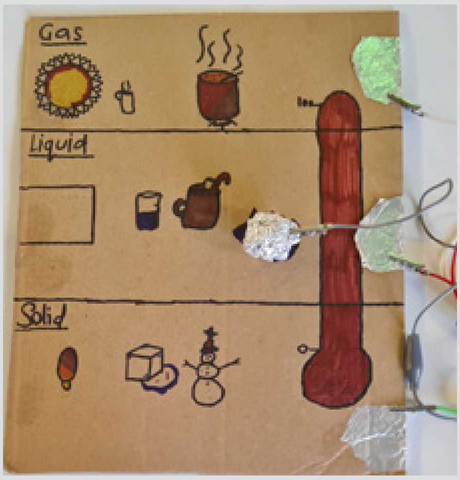


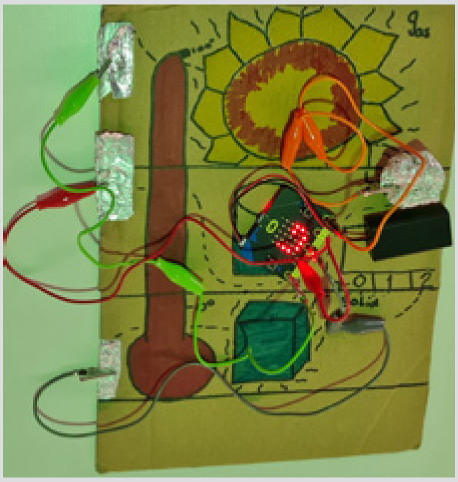
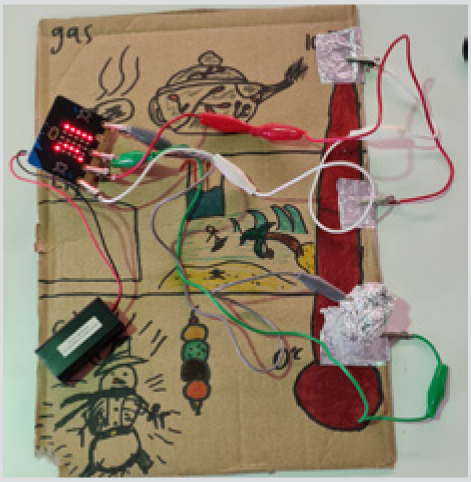
At the end of the lesson, Mr Sapsed reminds the students that the ultimate purpose of any learning is to share knowledge, and provide others with an opportunity to learn something new. Now that the students have successfully completed their project, they can showcase their ability in constructing a matter wand with the Micro:bit and educate the younger kids. So, as the final activity, Year 6 visit Year 2 students. They sit together in groups, all in their elements, trying to remember and use the same vocabularies they have just acquired (e.g. crocodile clips, states of matter, code, the Micro:bit), when showing their display: “You see how the lights come up when you do this (touching the states with the wand)? It’s reading the code”, says one boy confidently, addressing a group of Year 2 students and their teacher.

The teachers watching students showing off their work, continue to provide positive feedback and encouragement: “Well done showing persistence guys”, says the Year 2 teacher, making students proud and instilling confidence with their words of affirmation. Pictures below were taken from the final stage of the lesson.



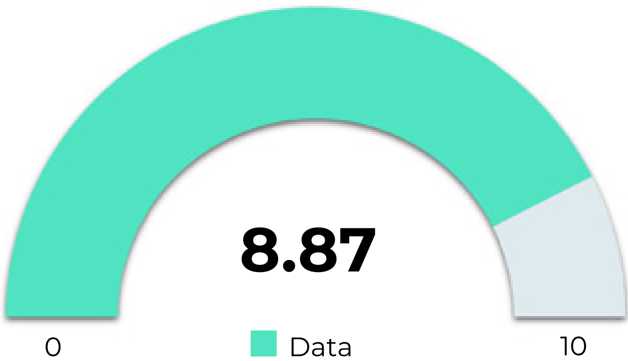
Examples of students’ matter wand project are provided below.



Students’ reflection on the matter wand lesson

As stated earlier in this report, after the completion of each lesson, Year 6 students and the classroom teacher engaged in a reflective practice, whereby they were encouraged to look back and reflect on their experience. To gauge students’ overall impression of the lesson, they were asked to provide a score between 1 to 10, 10 being the highest level of satisfaction. As the chart below shows, a rating of 8.87 indicates that the Micro:bit had established an environment in which students had fun while learning.



Evidently, one of the most favourite part of the lesson for students was sharing their project with Year 2, as expressed in the online journals. The activity urged students to communicate what they thought they had learned, while being in control and exercising their agency. The choice of words like "teaching" and "the little kids", suggests that learning with the Micro:bit was an empowering experience, allowing students to assume the role of an educator who had the necessary knowledge and autonomy to help others learn. Some examples from the journals include:

- The most exciting part was teaching the little kids.
- Teaching the year ones how a Micro:bit works.
- "Teaching" to 1T.

Signs of learning emerged from the journals as well. From a good understanding of the states of matter to learning "how to code the Micro:bit", "how to connect" it, and "how to make words come up on a Micro:bit", students proudly described what they had learned:

- Well I learnt how to code gas, liquid, solid and we had a ball of foil which had a black peg on it and we tapped the other foil and it said it was gas, solid, liquid so I give the lesson 10/10.
- We learned how to connect Micro:bits, and learning how to code a Micro:bit.
- How to code and make words come up on a Micro:bit.
- What I learn from this lesson is the state of matter. In the start I never knew what the meaning of state of matter and now I know.

The Micro:bit had also awakened their sense of curiosity to pause and ponder about the applicability of this new tool to other contexts and whether they could manipulate it to "teach deaf people", or use it in "maths and spelling", as a few students wrote:

- I am curious if I can code a game on the micro-bits and look forward to using it in the future.
- What other micro bit codes can I use.
- What else can you do with it.
- Help with coding like maths and spelling.
- Teach kids how to spell words.
- Teach deaf people to communicate in a different way, by reading off the micro bit instead of using sign language.

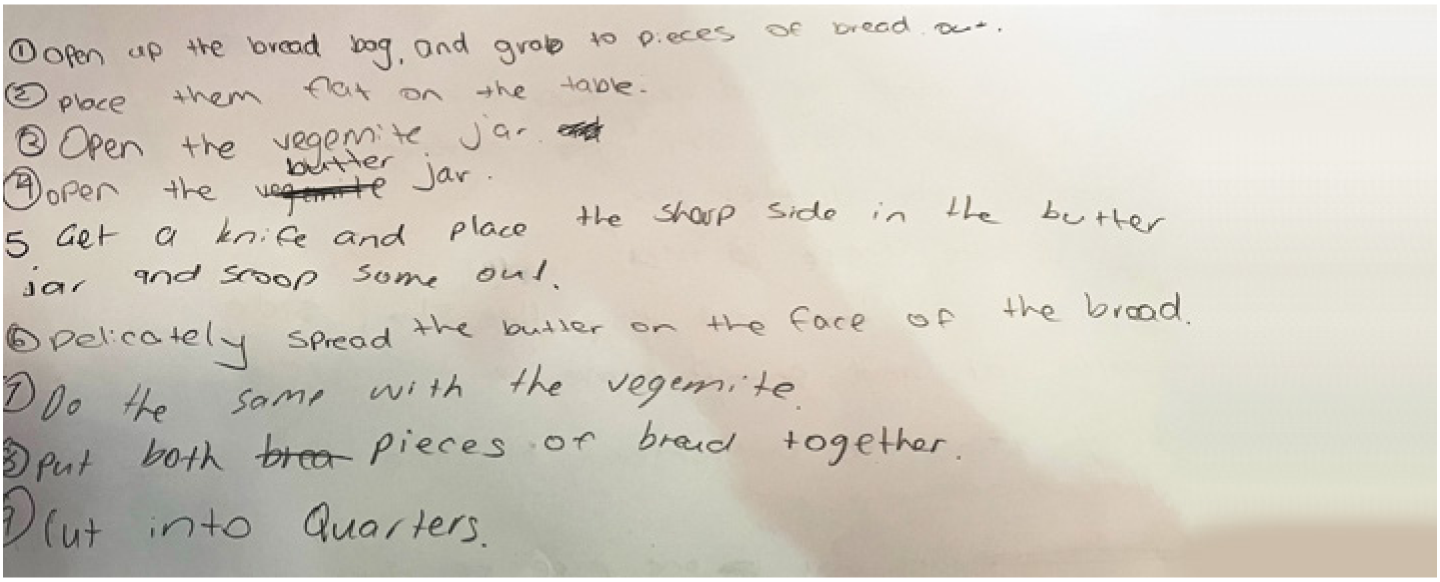
When prompted to reflect on the struggles they had and how they overcame them, most students identified coding and connecting the wires as the hardest parts of the lesson. Yet, as also revealed through the observations, collaboration and team work as well as persistence were the keys to success, as suggested below:

- We had trouble connecting the wires onto the matter cardboard, but as we slowly started to move it around and changed things up a little bit and became way easier to use :-)
- Team work and trying.
- By not giving up.
- I just gained the confidence to talk to them. That I can keep on trying cause we keep making mistakes and we learned from them and eventually got it.
- My group helped me do it.

Creating a Dashbot Zoo

Two lessons on the Digital Technologies concentrated on learning the language of algorithm, understanding its application in real life, and exploring how Dashbot could be coded to execute an algorithm and perform a task.

In the first lesson, students engaged in a fun activity to devise a recipe for “V&C sandwiches”—a clear example of an algorithm. Then, they prepared a set of instructions that described the exact steps they needed to take. Following the steps, they reached their goal of making sandwiches, as the following pictures show.



1 open up the bread bag, and grab to pieces of bread out.
2 place them flat on the table.
3 Open the vegemite jar.
4 open the ~~vegemite~~ butter jar.
5 Get a knife and place the sharp side in the butter jar and scoop some out.
6 Delicately spread the butter on the face of the bread.
7 Do the same with the vegemite.
8 put both ~~brea~~ pieces of bread together.
9 Cut into Quarters.

To connect the dots, in the second lesson, students were reintroduced to Dashbot—robots that needed a recipe (i.e. codes) to execute a command. So, working towards creating a Dashzoo for Kindy to walk through, Year 6 engaged in a given set of steps. The lesson on the Dashbot was captured through the second classroom observation.

Observation 2

Students start off with brainstorming and planning, which is a key component of this lesson, as they need to come up with a clear idea as to what animal to pick; how to sketch them on paper; how to create and stick them onto the Dashbot; and how to code them so that they follow instructions. Each task is timed and students are aware of their time limit, and that makes most of students keep up momentum and stay on task. The planning stage is a five-minute activity and generates animated discussions in most groups. While some groups are making good headway, some others hesitant to start, presumably because they do not know how to sketch their animal, wander off to have a look at their peers' drawings or do something else. However, by the end of the allocated time all groups complete their sketches and are ready to move to the next stage.

The animals students have selected include koala, chimps, elephant, cat, and chita. Using makerspace materials, students begin creating their animal within 15 minutes and once made, they stick them onto their Dashbot.

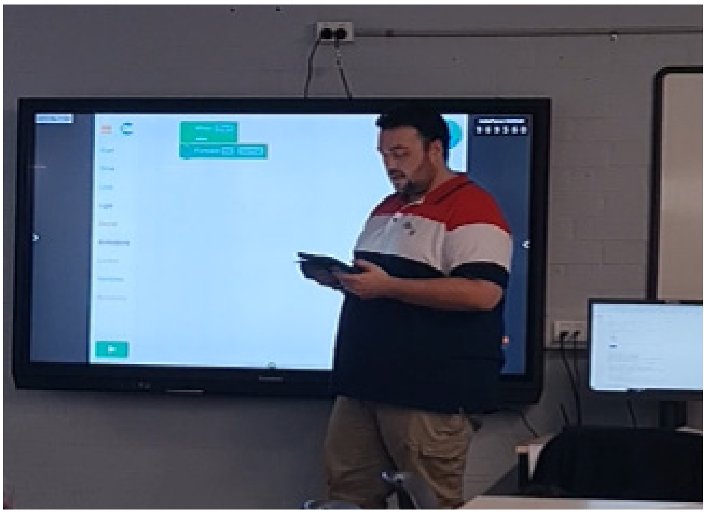
Central to the activity is "bringing animals to life", by coding the Dashbot to move, dance, and make noises or animal sounds. So, in the next part of the lesson, the teacher shows students how to connect and code the Dashbot. The app utilised for coding is Blockly and students are instructed to open the app on their iPad and create a new project to be able to start the coding process. Modelling each step of the coding activity, Mr Sapsed tests and tries different coding combinations to demonstrate how the Dash would execute the codes. For instance, he clarifies what the "Look", "Animations", "Sounds" and "Repeat" functions do, and provides useful tips:

Teacher (Excerpt 1): "You can use 'Look'. It actually controls the head. You can have the Robot look to the left, look to the right"... "There is a really cool one called 'Animations'. You can actually have the robot do a dance".

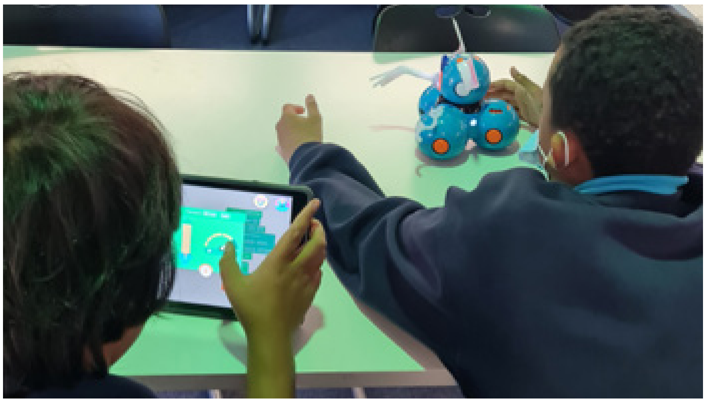
Teacher (Excerpt 2): "You see that light on the chest of the robot, that is actually a sensor, so it actually senses when someone walks in front of it. So, if you go to 'Sounds', you can select a sound (e.g. an elephant sound), so when someone walks in front, it keeps making an elephant sound".

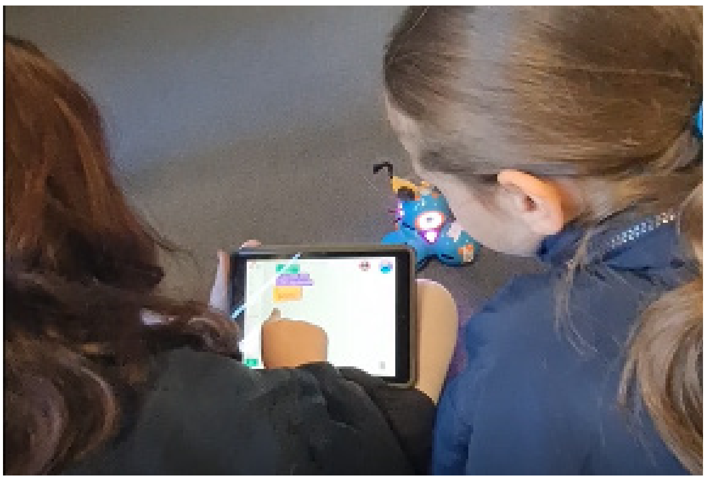
Teacher (Excerpt 3): "If your animal is moving forward, do not have them keep going forward and forward because they are going to hit a kindergarten kid, so, if you move it forward by 50cm, move it back by 50cm.

Teacher (Excerpt 4): "So you are not pressing 'play' all the time, if you go to 'Control' and select 'Repeat', that means your animal will just keep on moving, moving, and moving".



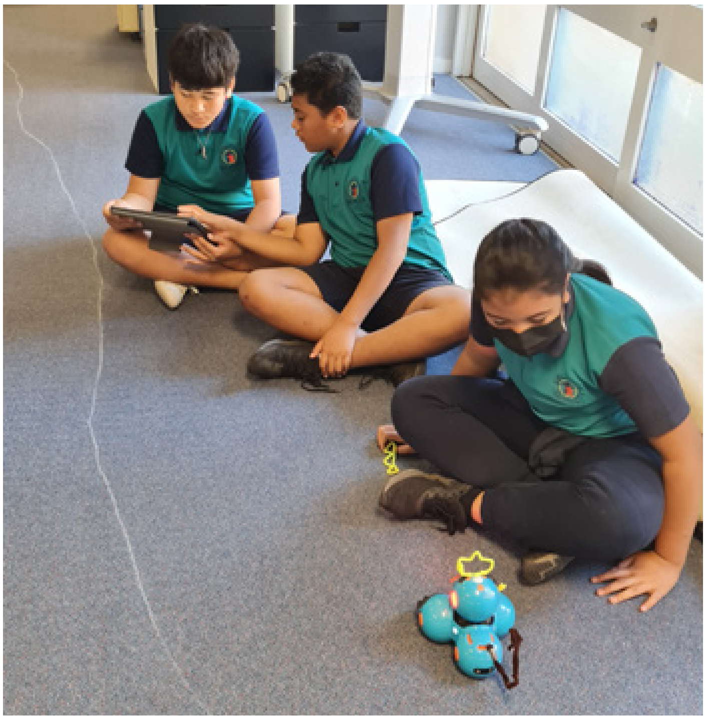
As also noted in the first classroom observation, a clear difference in the classroom climate is palpable once students get to work with the robots. Even those students who appeared slightly off-task in the first part of the activity, now seem enthusiastic and eager to make the Dash move. Collaboration and problem-solving, which are the hallmarks of technology-enriched activities, are abundantly clear in the classroom as students work in pairs to come up with codes to make their Dash sound funny and entertaining for younger students. They find the coding activity fairly straightforward, as they barely call out for help and manage to quickly code their animals.





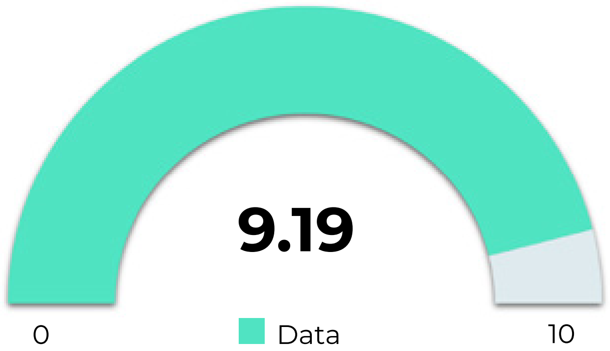
As the final part of the lesson, kindergarten students get invited to walk through the Dashbot Zoo, where Year 6 sitting alongside the path drawn on the floor, display their animal and describe what they can do. Kindy students mingling with Year 6, have a real blast and enjoy interacting with the robots. The lesson ends with participating teachers praising Year 6' s hard work and achievements, as one teacher states:

Teacher: "Your animals look amazing, you should be very proud of yourselves, well done!"



Students' reflection on the Dashbot Zoo lesson

Students participated in another reflective exercise following the lesson, to rate their experience, share their takeaways, and reflect on the classroom activities. This time, students provided a rating of 9.19 out of 10, which compared to the lesson on Micro:bit, proved to be even more popular and appealing to students.



Most of them found coding and creating animals on Dash an enjoyable and positive experience, even “the best thing in the world”, as one student mentioned. They sounded pleased with what they had learned and felt surprised by the versatility of the Dashbot that could act like “a real animal”, and produce a sound and move, once coded. In fact, the coding part was students’ most liked activity followed by the demonstration of the animals. Some examples from the reflections include:

- I learnt that the Dash bots could actually act as if a real animal.
- I learned about how to move a bot.
- I learned how to code a big robot.
- We got to make animals out of them + Sounds=fun.
- We built the Dash bot animals, I was very proud of big floppa.
- The Dash bots was the best thing in the world. I love it.
- The most exciting part was codling them and kindy looking at them.

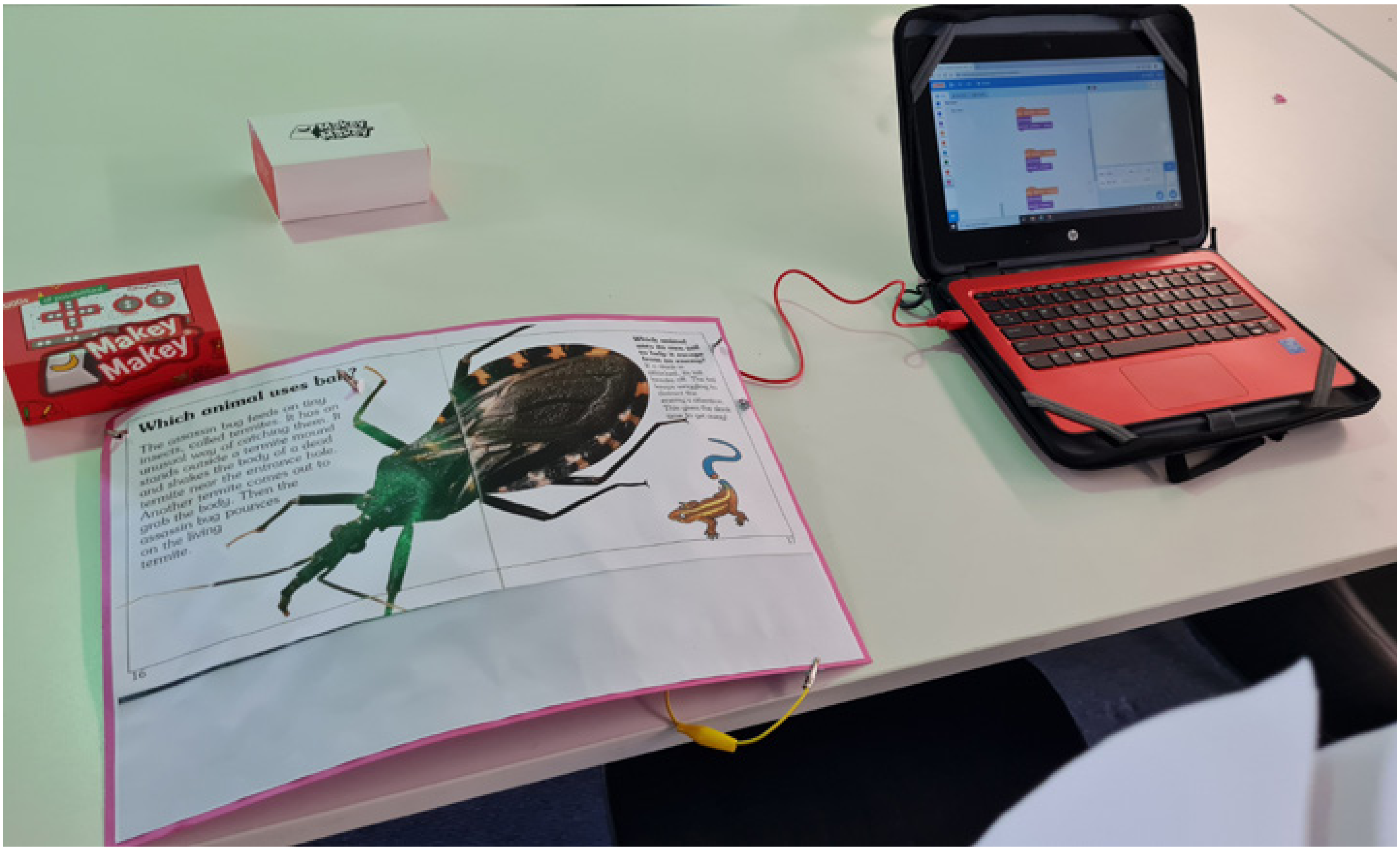
When discussing their challenges, they mostly cited the design and creation of the animals, while pointing out that they “did not give up”, worked with their “group members”, and “talked to [their] friends”, to find a solution.

- Probably designing the KOALA. It was difficult to find all the materials.
- Making the Dash bots but it was very challenging making a chimpanzee.
- Decorating the bot thing to make it look like an animal.

Wondering “what else” the Dash could do, or they could do with it, they conveyed their enthusiasm to explore other functionalities of the Dash. For example, they wanted to know if they could “make a shopping centre” with it, make it help “blind people walk and know where to go”, or get them “do stuff” for them, as a few students told us:

- What else we can do with them?
- Making new noise.
- To make a shopping centre.
- What else we can do to them and what else I can experience with them and I wonder what else they can do......??
- To help blind people walk and know where to go.
- Race.
- Get things while I’m doing something else or doing stuff for me to do it faster.

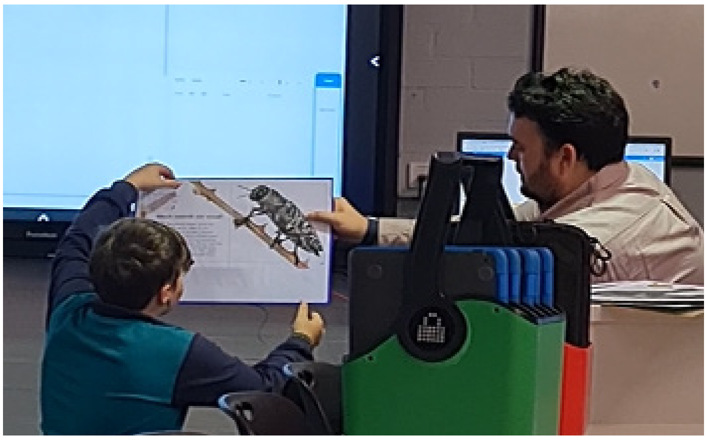
Making an interactive poster with Makey Makey



The third activity designed by Mr Sapsed for Year 6 was carried out using the Makey Makey kit and the coding program Scratch. The aim of this lesson was to demonstrate how the Makey Makey could bring printed text to life. Prior to the lesson, the teacher had photocopied pages of a book called 'Animal Food', put them on a piece of foil to make them look like small posters, and had recorded his voice.

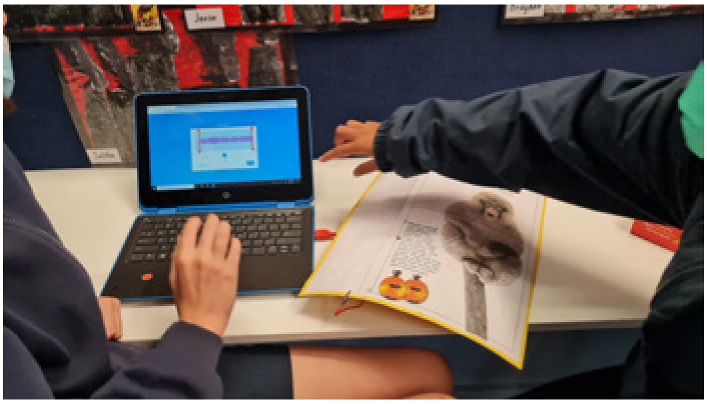
Observation 3

On the day of the third classroom observation, the teacher explains that he has recorded two headings and two paragraphs in advance, and coded the Makey Makey. He adds that now, for example "when 'up' arrow key is pressed, [it] plays sound recording 1, when 'down' arrow key is pressed, [it] plays sound recording 2". But, in order for the Makey Makey to read from the text, it needs a complete circuit. So, shoving the tip of the crocodile clips into the poster and using blu tack to secure them in place, he asks one student to press the Makey Makey key and touch the tip of the cable, and as he does, the Makey Makey starts to read the text, bringing the poster to life. "So, if your code is correct and you connect the cables properly, it is going to read the text", the teacher reassures the students.

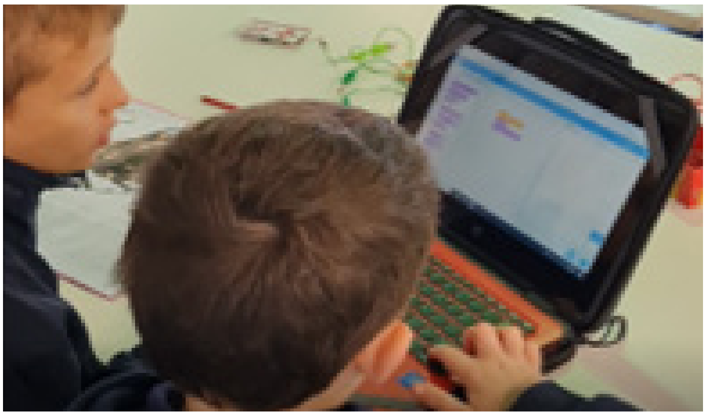


Handing each group a laptop, a Makey Makey, and a poster, the teacher splits the activity into three steps to simplify the procedure: (1) installing the Makey Makey onto the posters, (2) recording their voice reading the text, and (3) coding the Makey Makey— each step requiring communication and collaboration, problem-solving, and perseverance.

Working in groups of two, students have the flexibility to determine which task to perform first. Students in the pictures below, start with the recording piece. Even though only one student is required to produce the recordings, each pair collectively plan and decide on what should be done and how. The activity proves to be incredibly engaging and fun, with some groups making animal sounds and adding that as an intro to their recordings, trying to be creative or different.

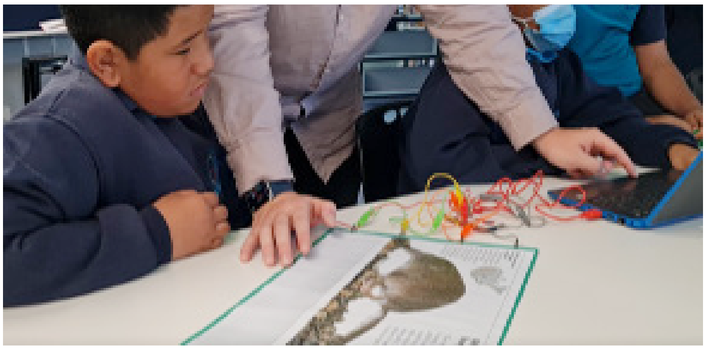


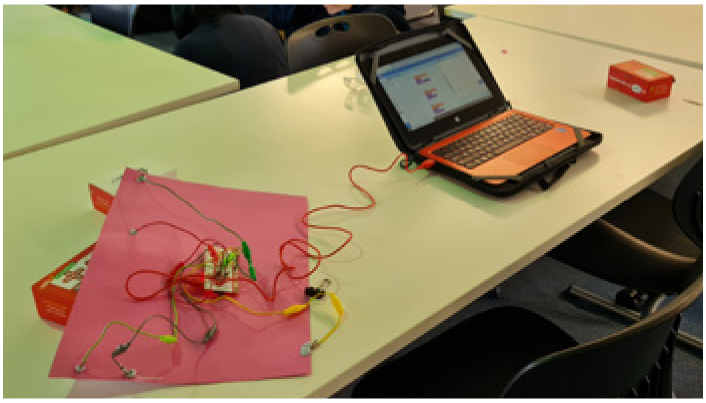
As students slowly progress through the three stages of the activity and hook up their poster to the Makey Makey to test their project, they experience unexpected setbacks. For instance, in one group there seems to be a mix-up as the Makey Makey does not follow the order in which the texts appear on the poster. But, it does not take long before the students realise that they have connected the wires to the wrong paragraphs and they need to reshuffle them.



Connecting the crocodile clips to the wrong section comes up again as an issue in another group. The three students working in this group have connected all the wires to one side of the poster (pictures below), even though one paragraph is on the left-hand side of the poster. Pressing the keys and testing their project, the teacher sounds pleased. But, he has one suggestion:

Teacher: "The only thing I suggest is these (referring to two of the crocodile clips) should go over there, next to the writing...can you do that? And then you guys are done, good job!"





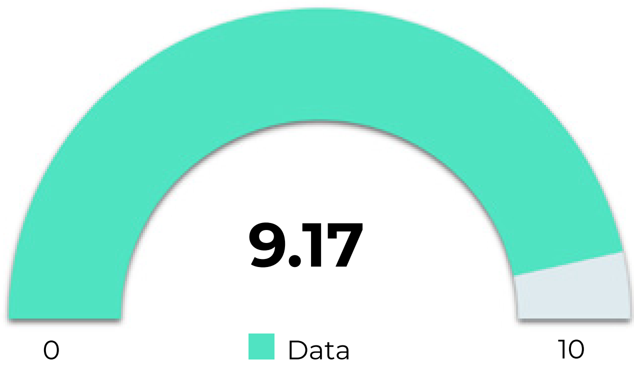
Students continue at their own pace; some lagging behind and some forging ahead with the activity. Interestingly, teamwork is not limited to individual groups but it occurs between groups as well. For instance, a few students who appear to have completed their project, go and offer their help voluntarily:

"You have to read this first", saying one student to a group of two who do not know where to start. "I am going to hold this up for you (referring to the poster), you just read this".

Eventually, all groups, persisting through the activity, code their Makey Makey successfully. The last part of the lesson, is another 'show-and-tell' and this time Year 6 invites Year 2, and demonstrate how the Makey Makey can bring the posters to life.

Students' reflection on the Makey Makey poster

Like previous technology-integrated lessons, there was another reflective practice following the completion of students' projects. Once again, students responded favourably to the questions in their reflective journals, giving a rating of 9.17 out of 10 to the activity conducted with Makey Makey.



Being intrigued to learn more about the Makey Makey, how it is used "in real life", and "what else" it does, they were proud that now they knew how to work with the Makey Makey, and were confident that they could help others "in case someone needs help coding", as one student wrote. They also told us that they found the coding exercise and showing their artefacts to the younger kids the best and most fun part of the day.

The lesson taught one student something beyond coding the Makey Makey. In her journal, she underlined the importance of listening closely to the teacher and using the allocated time efficiently to obtain goals. Her simple takeaway mirrors the findings of a study that suggests digital programming tools (e.g. Makey Makey and Micro:bit) implemented through social interactions help students master their own behaviours (Linask, 2012). Seeing it as a valuable lesson applicable to other situations, this student had realised that certain competencies and behaviours (e.g. listening carefully to the teacher), were prerequisites to success because she had managed to "make progress" only when she had listened attentively.

Examples from students' journals are provided below:

- I love this lesson but now I know why listening is important cause I didn't know what to do but since I had listened more we started making progress doing it and time is valuable use it wisely and listen so you can do things right and can really help.
- Everything was fun I loved it all it was amazing learning how to code.
- Showing my work to the year 2 kids and showing them how to use the Makey Makey and our animals, also my favourite part was record my book.
- I have learnt how to use Makey Makey and I loved teaching 1T.
- Coding the page of a book.
- Was coding it to our voices.

As observed throughout the lesson, students struggled a little with connecting the crocodile clips, which emerged from the journals as well, where they described their main challenges as "attaching all the pegs", "finding the place it [crocodile clips] goes", and "connecting the crocodile cords to the paper". Once again, they told us that team work, perseverance were the strategies they employed to address the problems:

- Talking-coding and working.
- I worked hard and got help by Mr Sapsed when I mostly needed it.
- Got help.
- Talking with friends.

YEAR 2'S ADVENTURE WITH BLUE-BOT AND DASH

In addition to the data collected from the Year 6, three classroom observations were conducted on a Year 2 class at Guise PS. The learning activities students participated in included learning addition and subtraction using Blue-bot; sequencing events with the help of Blue-bot; and estimating length with Dash Robot (Figure 2). Pictures and notes were taken during the observations for further analysis. Researcher's notes were also used as prompts in the final interview with the teacher. In the following sections the classroom activities run for each lesson are described.

Year 2	Activity	Resources
Lesson 1: Blue-bot	Teaching addition and subtraction using Blue-bot.	Whiteboard/markers Blue-bot Blue-bot mats Dice
Lesson 2: Blue-bot	Using the text 'Rosie's Walk' to learn sequencing of events. Using the Blue-bots to sequence the events of the story.	Blue-bot Blue-bot mats Sequencing cards
Lesson 3: Dash Robot	Estimating and measuring length with Dash	Dash Rulers

Figure 2. Year 2 lesson plan

Learning addition and subtraction with Blue-bot

A fun and engaging activity, which comprised a slightly competitive element and stimulated a lot of thinking and discussion, was performed using the Blue-bot. The Blue-bots, as real objects that allow students to practice abstract maths concepts like addition and subtraction, were strongly favoured by students as suggested by their initial reaction to the teacher's introduction of the bots:

Teacher: "we are doing an activity with Blue-bots today".

Students all together: "Yay"

The interest and engagement did not wane throughout the lesson; rather being rewarded for solving the math problems with coding the Blue-bots, kept students competitive and motivated. As students were already familiar with coding the robots, they did not receive any instructions on how to make the bots turn and move. So, the teacher kicked off the "game" by getting students to pair up and sit on the floor in circle.

Rolling two different dice, she explains that they are going to write the number sentence on their whiteboard, and the person who works out the answer first, can code the Blue-bot. So, students are facing two exciting challenges; one to get the maths question right, and two, to code the Blue bot correctly so it lands on the right number on the Blue-bot mat. Verbalising the first question, she rolls the dice: "9 + 3?" Students race against each other to solve the equation, in order to get to the next challenge.

Those with a wrong answer, are encouraged to "try again", and the two girls who win the first competition start coding the Blue bots. "How do you get to number 12? "What do you need to press?" asks Ms Wang.

The girls confidently put the codes in and once they do, the Blue bots start moving towards number 12. “Awesome! You won the competition!” Says the teacher while happily clapping.

She puts another question to the groups. “11+4?”, and gives students time to write their answer on their whiteboard.

Having the right answer, the boy in the picture gets to code the Blue-bot. As the Blue-bot moves forward, it stops on number 16, which is the wrong number. Did you forget to press ‘Turn’?” Asks Ms Wang, but then she realises the Blue-bot is stuck.

The teacher suggests that the student “try the battery”, and as he does, the Blue-bot starts moving. “So the code was right!”, says the student proudly. Nodding encouragingly, Ms Wang explains that: “You put the instruction in and it moves. Good work!”.

Sequencing story events with Blue-bot

The second lesson was somehow similar to the first one in that the Blue-bot was implemented and coded to land on a right spot. But, this time the activity involved learning sequencing and coding the Blue-bot to put the events in correct order to retell a story. The lesson starts with students listening to the story called “The wall in the middle of the book”.

Ms Wang explains that the aim of the lesson is to finish a maze that consists of pictures from the book they had just listened to. The maze shows the beginning and the end of the story, yet the rest of the pictures are out of order. Their task is to code the Blue-bot to sequence the events of the story, as they occurred in the book.

“Who can tell me what happens next?” asks Ms Wang, encouraging students to retell the story in their own words.

Remembering the correct sequence of the story poses a challenge, but not coding the Blue-bot. As also documented through the first observation, most students feel confident with the coding exercise and are excited for the Blue-bot to move and turn to land on the right picture.

Estimating and measuring length with Dash Robot

The final lesson observed for the purpose of this report, was an activity conducted using the Dash robot to measure length. But, the first step for students was to learn what a centimetre is and how we measure it.

Ms Wang plays a short video demonstrating lengths of different objects, and explains what is meant by longer/shorter than 1 cm. Ruler is introduced as a tool to measure length of objects:

"This is what 30 cm looks like. 1 cm is really teeny-tiny, can you show me 10 cm on the ruler?", asks Ms Wang, giving Year 2 practice in guessing different lengths.

The next part of the activity involves the Dash Robot, for which students need to "estimate" the length of different lines drawn on the floor.

"What is estimate?" asks one student, to which Ms Wang replies "estimate means to have a good guess". She clarifies that they are going to estimate how many centimetres the different lines on the floor are and use Dash to check whether they are correct. So, she challenges the students:

"How long do you think this line might be? Remember that is how 30 cm looks like (holding up the ruler). Do you think that is longer, shorter or 30cm?"

"100 cm", someone replies.

But, in order to check how long the line actually is, students need to code the Dash:

Teacher: "Remember when we were using the Blue-bots we had to code them and tell them the instructions to move? We are going to code the Dash to measure how long each line is".

Using the Scratch program, Ms Wang puts in the first code on the iPad, modelling how the coding should be done:

"so, I am going to move it forward by 100cm, and then press play".

The Dash starts moving forward and stops at the end of the line.

"Wow, I think that actually was 100 cm. Excellent!", cheerfully remarks Ms Wang, while she further adds:

"That went really fast but we can actually make it more slow by changing the speed here (holding up the iPad to show the setting). Do you want to change it to 'slow' and then press 'save'?, addressing the student who had made the correct estimate.

This time the Dash moves slower over the line drawn on the floor, giving the student a sense of achievement: "This is so slow, look!", the girl shouts triumphantly.

After scaffolding the coding exercise, the teacher hands over the iPad to students, making them in charge of the coding task, while providing guiding questions:

Teacher: "How many cm do you think that line is? 40 cm?

Student: 30

Teacher: "You think that is 30cm? let's try. Press the arrow. Good! And do you want the speed to be Fast, Slow, or Medium?"

Student: "Fast".

Teacher: "Ok! Press that arrow and then press 'play'".

The Dash moves forward but it stops halfway before reaching the end of the line. Ms Wang provides a tip:

"Ok. It did not quite finish it. There was a little bit more, so you might have to go up. Let's try another code. Do you want to try 50?".

This time the Dash finishes at the end of the line, suggesting that the line was 50 cm.

Students waiting eagerly for their turn, continue to practice, while the Dash proves to be an effective tool to assist with measuring length and teaching coding.

DISCUSSION

Although the observations served as the primary data source in the research, the final teacher interview, as well as assessment of students' learning progress performed by Mr Sapsed shed further light on the applicability of the Inventor Robotics and Tablet Robotics kits in a Primary school setting and their potential for enhancing student learning experiences. In this section, the data generated from the interviews and assessment rubrics are discussed in light of previous studies on STEM technologies to provide further insight and direction for the implementation of the stem.T4L equipment.

Do the Inventor Robotics and the Tablet Robotics improve student outcomes?

Growth in learning outcomes

Rahman (2021) poses critical questions in his research on STEM: "How can we justify that the robotics-enabled STEM education actually enhances the learning outcomes of the students (learners), and what are the scope and elements of the learning outcomes?" (p.2). Evidently, in this study, learning gains were obtained at an educational level (content knowledge), however minimal, as evident in the classroom assessments. As mentioned earlier, to help us determine the extent of growth in student learning gains systematically over the course of the study, Mr Sapsed completed an assessment rubric comprising of a set of indicators derived from the curriculum documents. Students were evaluated against five indicators of the Digital Technologies at the beginning (pre) and at the conclusion of the study (post) in Term 2 (Figure 3). The assessment indicated that the majority of students were at the B category (Working at), at baseline for the five indicators. In the post-assessment, while still most students were sitting in the same category, modest progress was observed in the number of students moving from C to B or from B to A categories across the five indicators. For instance, whereas 8 students were at C for indicator 1 (identify data required to formulate algorithms to improve a process) at baseline, 4 students progressed to B by the end of the Term, leaving only 4 students at C. In his assessment, Mr Sapsed further pointed out that:

"Students, prior to these lessons, hadn't been exposed to creating their own algorithms based on their own data – they had just been told what algorithm to make. Through lessons where they had to create their own code, students developed the skill to identify data needed to improve their code" (Mr Sapsed, final class assessment).

For indicator 2 (design, modify and follow simple algorithms), 19 students were at B by the end of the study. Although 16 were already in this category, the ample "exposure to simple algorithms, where they had to follow, design and modify them" consolidated their learning, helping them to go "from following algorithms to then being able to design their own". But, the most substantial progress was recorded for the indicator 4 (present data as evidence in developing explanations), where only 2 remained at C from an initial 10 students, with 6 students advancing towards B. Mr Sapsed attributed this gain to a heightened understanding of algorithms facilitated through the many opportunities to use "evidence", and "adjust", and "describe" their code.

"Students had a number of opportunities over the duration of this program to demonstrate their understanding using evidence in their code. Students, were taught how to adjust their code, were then able to describe why this code was made this way as they had an understanding of how algorithms worked. Furthermore, using sensors such as the Makey Makeys enables students to develop an understanding of different inputs when coding" (Mr Sapsed, final class assessment).

Later in the final interview, he reiterated the importance of employing STEM technology especially in teaching coding and algorithms, as otherwise such learning gains would not have been attained:

“I wouldn't say you would typically see improvement cause...I think it would be very difficult to see [progress] particularly in the coding, if you weren't actually using these resources or these devices. I mean, you definitely could do paper coding and things like that, but then you're just making work harder for yourself. So, I think definitely using these kits and technology to assess those skills did help with the improvement as we saw in that assessment” (Mr Sapsed, final interview).

Science ST3-2DP-T/ ST3-3DP-T/ ST3-11DI-T	**C** **Working Towards**		**B** **Working At**		**A** **Working Beyond**	
Indicator 1. identify data required to formulate algorithms to improve a process	Is unsure of what data is needed		Can successfully identify the data that is required		Is able to customise data values	
	Pre	Post	Pre	Post	Pre	Post
	8	4	15	17	5	7
Indicator 2. design, modify and follow simple algorithms	Is unable to follow simple algorithms		Can design, modify and follow simple algorithms		Can design, modify and customise more advanced algorithms	
	Pre	Post	Pre	Post	Pre	Post
	4	2	16	19	8	7
Indicator 3. extend sequences of steps to provide a series of possibilities through branching	Is unable to extend algorithm sequence to accommodate branching		Can use branching to extend sequence of steps to provide a series of possibilities		Can extend sequence of steps into a greater series of possibilities through more advanced branching	
	Pre	Post	Pre	Post	Pre	Post
	10	4	16	19	2	5
Indicator 4. present data as evidence in developing explanations	Provides anecdotal explanations without data, or uses data that does not support explanations		Presents relevant data as evidence when developing or communicating explanations		Presents detailed or extensive data to support explanations or to identify hypotheses for further investigation	
	Pre	Post	Pre	Post	Pre	Post
	10	2	14	20	4	6
Indicator 5: work collaboratively to share, appraise and improve ideas to achieve design purposes	Is unable to collaborate with others. Is not open to share and receive feedback.		Can successfully work in groups		Work seamlessly in group activities, share ideas openly, and can act on feedback to improve ideas.	
	Pre	Post	Pre	Post	Pre	Post
	2	2	18	19	8	7

Figure 3, Syllabus outcomes measured by Mr Sapsed

Students' reflective journals added further support to the findings on gains in content knowledge, arguably in both procedural (i.e. know-how), as well as functional knowledge (i.e. the ability to transfer new learning to other situations). We discussed above that students were able to describe in simple terms the steps they had taken to code their robots (procedural knowledge). In response to the question "How can you apply what you have learnt and discovered today to solve everyday problems?", some students wondered about, for example, the applicability of a robot like Dash for helping "blind people" find their way, or teaching younger students how to spell words with Micro:bit, displaying basic level of functional knowledge.

Learning gains were discussed by Ms Wang as well, in the online interview conducted at the end of the program. She underlined the "fantastic" role of the stem.T4L kits in "teaching students the basics of coding":

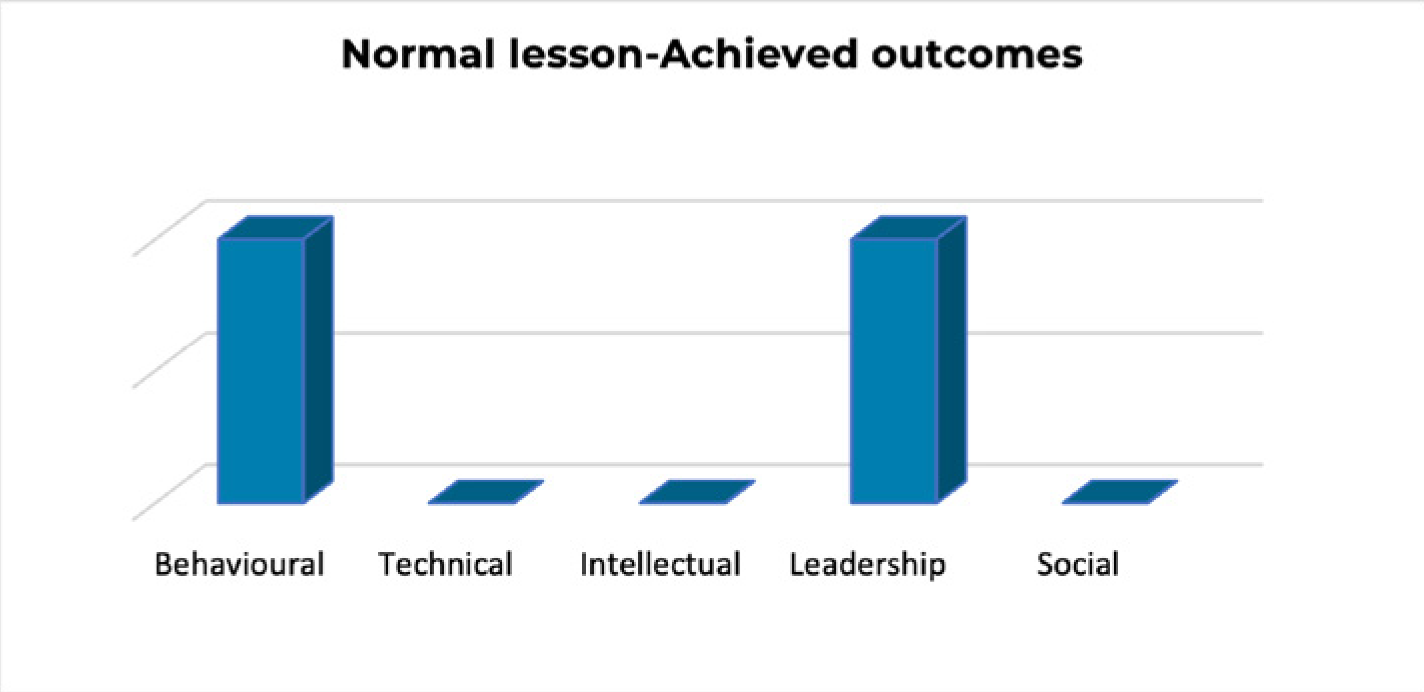
"So, we learned about measurement and rather than just drawing a line and measuring the line, we were able to code the dashboard to make estimations about how long we thought the line was and then code the dashboard to move along the line and check whether we were correct. So with that lesson the kids were actually taking the time to think that technology doesn't just happen on its own. It doesn't move on its own. You actually have to put in the code and the instructions for it to be able to move. And they saw once it was coded correctly, it moved correctly, but if they coded it incorrectly, it wouldn't do what they wanted and so getting them really to think about each step by step and putting that into the code" (Ms Wang, final interview).

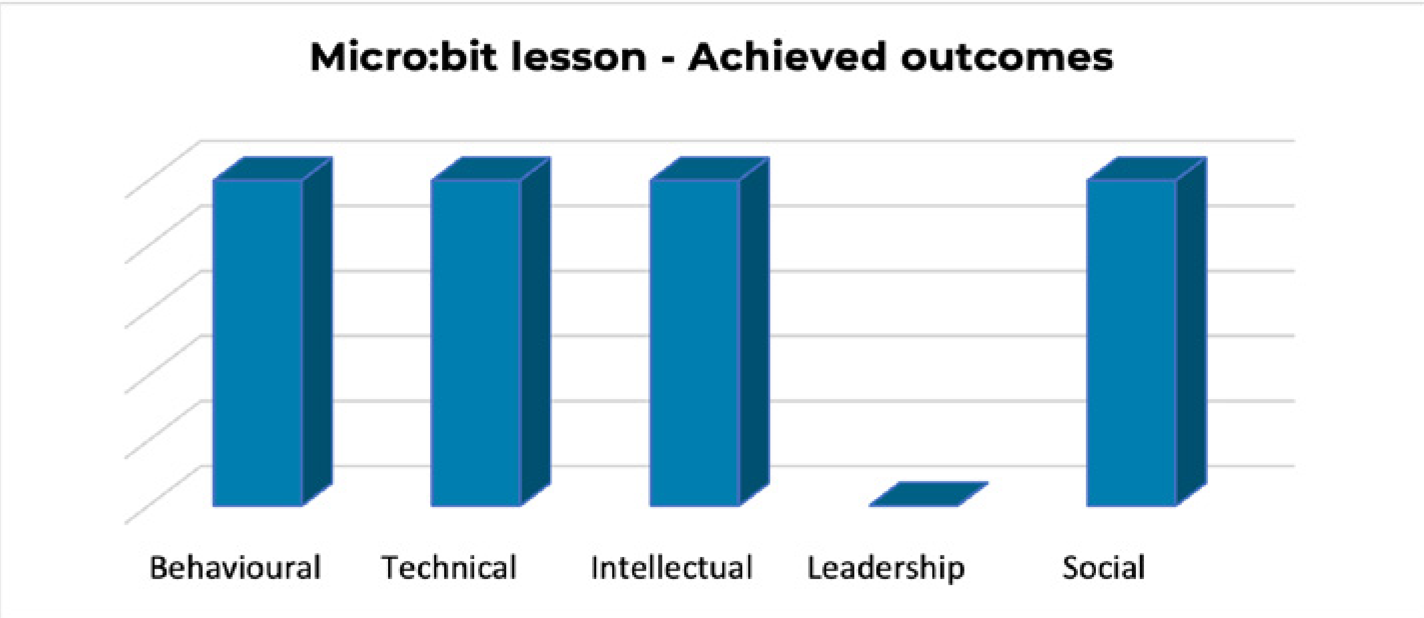
Development of soft skills

There is widespread agreement on the positive impact of robotics on students' problem-solving, collaboration, critical thinking, engagement, and autonomy (Carbonneau et al., 2013; Johnson et al., 2016). In a same vein, in our study, it was found that working with physical manipulatives (e.g. Dash, Micro:bit, & Makey Makey), yielded improvements in the soft skills, categorised into behavioural (e.g. engagement, teamwork); technical (e.g. ICT skills, troubleshooting); intellectual (e.g. problem-solving abilities, critical thinking); leadership (e.g. organizational and planning ability); and social (e.g. interpersonal relationship) domains (Rahman, 2021). While the development of certain skills was more pronounced in some lessons (e.g. "Their group work and communication skills were on show during this lesson", Mr Sapsed, 2nd reflective journal), most of the said skills were applied and broadened in the STEM technology- enriched environment. For instance, reflecting on the lesson on Dashbot zoo, Mr Sapsed wrote: "I feel like all those outcomes were achieved/touched on today". The lesson on Micro:bit produced almost the same outcomes, where students' problem-solving, and critical thinking, for instance, were tapped into:

"Students were challenged to work together and persist during a multi-layered lesson. There were technical parts of the lesson that required critical thinking and problem solving… Students had to work together and share resources" (Mr Sapsed, 3rd reflective journal).

As mentioned above, one of the reflective journals provided by Mr Sapsed was based on a normal lesson, with no technology-integrated activities included in the lesson. When we compare the three robotics-enabled lesson reflections with that of the non-tech lesson, we observe that using robotics as a pedagogical resource presents unparalleled opportunities for broadening a range of soft skills, most of which remain untouched in a normal lesson (e.g. technical, intellectual, social), as indicated in the charts below.





Although a non-tech activity is likely to generate engagement and teamwork/collaboration (behavioural outcomes) as suggested in the first chart, enthusiasm, curiosity, interest, effort, concentration, and positive emotions, as indicators of higher level of engagement (Skinner & Belmont, 1993), are more prominently displayed when students perform an activity using robotics. Ms Wang's comparison of robotics vs non-robotics lesson provided further support for this argument. During the final interview, she remarked a few times that she always gets "*a lot more engagement and everyone wants to have a turn [when the STEM technology is present], whereas when there's no technology, everyone is just half asleep*". She also had witnessed subtle changes in the extent of collaboration and teamwork displayed amongst students:

"There definitely is a big difference between not using the kits and using the kit. There is a much higher level of student engagement and everyone's putting up their hand to have a turn and also the teamwork as well. When someone is putting the code incorrectly, another could be like 'oh you have to do this, you have to do that', and they're more willing to help and share their ideas on it. Whereas without the kits they're all a bit shy. No one's really putting up their hands to have a go" (Ms Wang, final interview).

Pedagogical strategies facilitating the implementation of the kits

In their everyday practice, teachers adopt a vast range of pedagogical techniques and strategies, aligned with learning objectives, and tailored to suit students' learning needs and skill level. By the same token, in teaching with robotics, one of the key considerations is the aptness of the pedagogical strategies employed. In their study on teachers using physical computing devices to teach programming to Years 2 to 7 students, Kalelioglu and Sentence (2020) found that commonly used methods were pair programming, tinkering, copying programs, explaining code verbally, and demonstrations/live coding. As one of the objectives of this study, we also explored the strategies utilised by the Primary teachers when implementing the stem.T4L technology.

As discussed earlier in this paper, Mr Sapsed applied an "I do, you do" approach in the lessons he taught using the robotics. In his interview, he underlined the significance of scaffolding and modelling the tasks, especially for students from low socio-economic status with no prior exposure to technology:

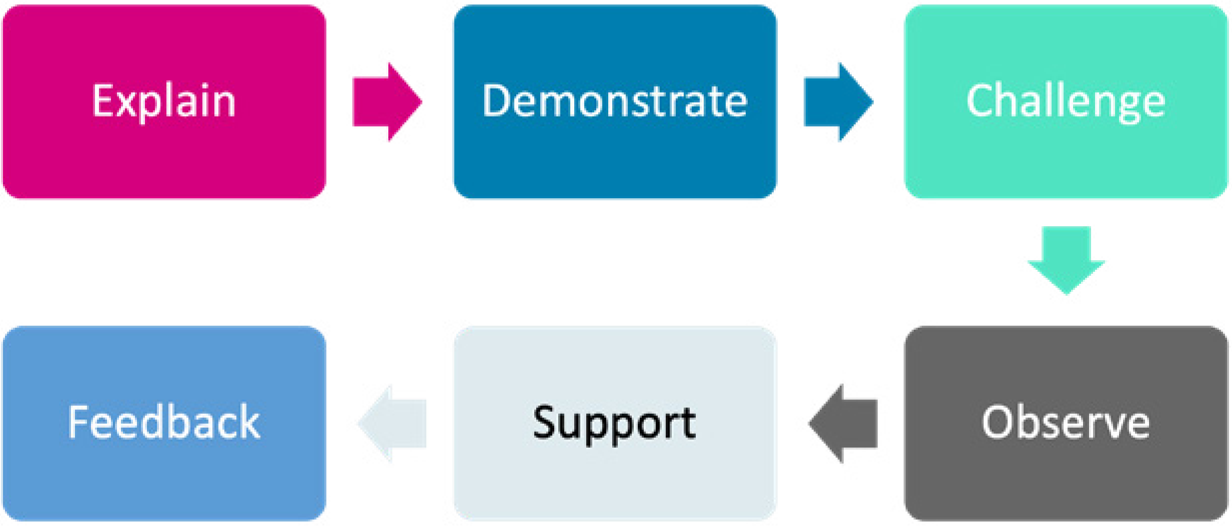
"You need to explicitly teach what you want them to know when you model it, and then they have a go and do them themselves and that "I do, you do" is just a reiteration of that and I think that's really important when you're exposing students to technology they haven't used or seen before. They really need to see how you do it, then need support doing it themselves and then they have a go at doing it themselves. Because if you gave students an iPad and said "go and code something', they would not know where to start" (Mr Sapsed, final interview).

Voicing the same sentiment, Ms Wang also viewed a step by step approach the most effective tactic when introducing new technology:

"Really taking it step by step and guiding them through the process, especially if it's a new concept or a new technology that they haven't used before, or haven't seen before. And as Mr Sapsed was saying in our socioeconomic area, they would have very little exposure to the kinds of technology that we're using in class" (Ms Wang, final interview).

The "I do, you do" approach as an overarching theme consisted of key stages as revealed through classroom observations. During the "I do" phase, Mr Sapsed would initiate with an 'Explanation' of the class project; the steps required to take; and the overall objective, which was to share the new-found knowledge and to inform younger kids of the possibilities that technology offers. Following the Explanation stage, he would perform a quick and simple 'Demonstration' of the task (e.g. creating a 'new project' in the coding platform, modelling the coding etc.). To generate motivation and awaken students' curiosity, he would then 'Challenge' them to have a go and experiment independently (e.g. "I want to let you do the next [coding] yourself"…"Can you do that for me guys?"). As students would start to take baby steps towards completing the activity, practicing their agency, he circulated around the room 'Observing' them fail or succeed. However, he was not just there to watch, but to provide 'Support' through each step of the way by giving effective 'Feedback'. His ongoing feedback, praise and positive reinforcement would further encourage participation and consolidate student learning. The diagram below depicts the stages of the "I do" phase.

Stages of the “I do” phase



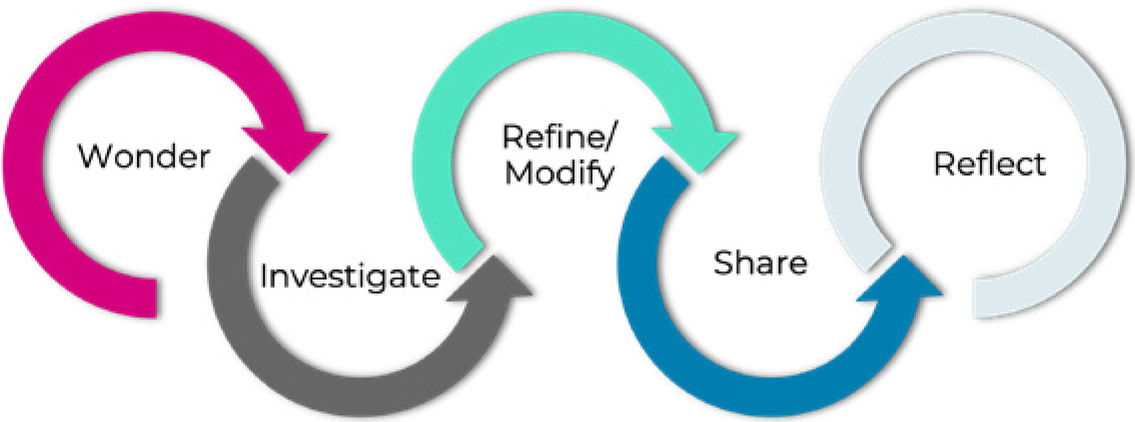
During the “You do” phase, students were in the driver’s seat, in charge of their learning and driven by their avid interest in working with the novel technology. Encouraged by their teacher to immerse in an iterative process of ‘Wondering’ and ‘Investigating’, students would continue to ‘Refine’ their understanding of coding, and ‘Modify’ their projects until they achieved success. But as advised by their teacher, their main task was to pass on and ‘Share’ the knowledge by demonstrating their artefacts to younger kids. Not only was this activity highly enjoyable, but it cultivated students’ agency and further consolidated their learning, as they acted like a teacher in charge of educating younger kids. Mr Sapsed in his assessment considered the ‘sharing’ task conducive to students’ progress in indicator 4 of Science (present data as evidence in developing explanations), in particular:

“This was evident when students were showing their work to the younger children. Year 6 students were able to teach the younger students and present data to inform them/teach them. Students were presenting data of different states of matter (gases, liquids and solids) to help educate” (Mr Sapsed, class assessment).

Previous studies also attest to the fact that sharing thoughts with others and talking about their learning and what they have created lead to students’ higher control over what they are doing (Kalelioglu & Sentence, 2020).

The final step for students was ‘Reflecting’ on their learning and considering how they could transfer and apply their knowledge of technology to other real-life situations, which was done through their participation in the reflective practice. Different steps of the ‘You do’ phase are presented below.

Stages of the “You do” phase



Challenges and limitations

The implementation of any educational innovation is always mingled with unforeseen challenges and some reservations on the part of teachers as the enablers of change. There are studies that indicate challenges usually originate from three different sources: teachers' negative beliefs and attitudes, teachers' limited knowledge and expertise, and lack of access to training and support (e.g. Asghar et al., 2012; Nadelson et al., 2013). The research conducted on the stem.T4L project over the last four years, while corroborating previous studies, reveals that one of the major barriers to integration of STEM technology is time; time to explore and experiment with the unknown, time to upskill, and time to effectively implant the resources and equipment in teaching and learning materials.

In our discussion with the two Primary teachers we delved more deeply into the constraints and limitations of integrating the equipment, and interestingly being time poor was brought up as a barrier that teachers in their school were dealing with. Being the only teachers at the school who had had the chance to use the stem.T4L technology, Mr Sapsed and Ms Wang both acknowledged that with so many other responsibilities and concerns on teachers' agenda, finding the time to sit down and explore the potential of the equipment is simply too difficult. But what serves as another significant deterrent is some teachers' lack of knowledge of and confidence with the technology itself because "you can't teach something you don't know", as Mr Sapsed pointed out:

*"The teachers are already so busy with so much else going on, it's really difficult just to add another layer of something that they might not be confident with when there's already so many other pressures and focuses. You don't want to say 'we've got this new resource, go and do it'... it's hard to get them to do something that they might not have a lot of knowledge about... I've had a look at the STEM library for the activities and they're fantastic. It's just challenging for classroom teachers with everything going on to really sit down for a good hour or so to get to know it themselves because you can't teach something you don't know" (*Mr Sapsed, final interview).

Ms Wang, agreeing with Mr Sapsed and drawing on her first-hand experience highlighted the fact that it can be "tricky" for teachers if they do not know how to fit this new addition into their lessons and that is why she believes it is important to have a support system—someone to bounce ideas off and collaborate with.

"... having [Mr Sapsed] has been great because you show him and he's like 'yeah, we could do this, we could do that'. So, it's been a little bit tricky integrating it in the classroom" (Ms Wang, final interview).

When asked to comment on the existing limitations of the available tools and resources and the overall stem.T4L program, if any, the teachers identified the ratio of kit equipment to students. Although the decision on kit-student ratio has been made with an eye to encouraging active collaboration amongst students, the Primary teachers found the kit ratio a hindrance at times. In the context of Primary school, where the average number of students "is upwards of 30", having 10-12 sets of equipment would mean some students had to wait for a turn and "do nothing" while their peers had a go, as both teachers argued. They found it crucial for students "to have their own go", "make their own mistakes", and have a one-on-one experience with the kits:

"The challenge that I found with the kits is that they only come in sets of 10 to 12... so we made it work by focusing and assessing on the collaboration side of it. But I think when you're working with technology, it's really important for students to have their own attempt at it and it can be a bit challenging when you only got 12 Micro:bits or 10 or so Spike kits or only 12 Blue-bots and students are waiting or just doing nothing while someone else has a go. So, I would say the biggest challenge with the kits is, not having access for students to have one-on-one turns of the resources in a classroom setting" (Mr Sapsed, final interview).

"I did notice the same thing, that there's not enough for one to one where some of the activities are a little bit challenging because it needs to be one-on-one so the kids can really have their own go, make their own mistakes. And whereas sometimes when they're working partners or groups, one might take over and the other student might not have a go at it. So that's probably the biggest limitation there" (Ms Wang, final interview).

In spite of the constraint that the equipment ratio had imposed occasionally, both teachers strongly believed that the integration of the resources would make learning more "engaging" and "fun". At the conclusion of the interview, they both highly encouraged other classroom teachers to dedicate some time to unpack the potential of the equipment and take active steps towards embedding such resources within their classrooms because "it is worth it":

"It's definitely worth investing in and using and learning about using it in the classroom and because it just enhances your lessons, but it does take time to sit down and learn how to use it and it does take a bit of time to look at your program and see how you can integrate it authentically without just doing a lesson here or lesson there sort of thing, but it is worth it" (Ms Wang, final interview).

"It's really important for students to be able to be exposed to these different technologies. But for teachers it can be very daunting to master the kits with all these resources and manuals and learn how to use it. But if you want to get into it, just have a go yourself, see how it works. I'm considered an expert, I guess, but I've failed so many times in my career when I was implementing technology. We just learn from failure. I recognise that it can be very daunting to take some unknown technology into your class and try and teach a handful of kids with it. But I can say that it gets better and it makes a lesson much more fun to the students as well" (Mr Sapsed, final interview).

CONCLUDING REMARKS

The aim of the present research was multi-faceted, centering around Primary teachers' innovative ideas for the application of the Inventor Robotics and Tablet Robotics; and students' response and engagement with the STEM technology to pinpoint obstacles and successes. The data obtained from Year 6 and Year 2 students suggested that the technology-assisted learning environment generated positive outcomes. Although encountered with unexpected challenges such as connecting the Dash-bots to the iPads, attaching the crocodile clips to the posters, making the Dash-bot look like their animal, and coding the robots to move the way they wanted it to move to name a few, students remained on task and actively engaged in the activities. As they told us in their journals, and also documented through the classroom observations, they followed the teacher's instructions step by step (guided by the 'I do, you do' approach), drew upon trial and error, and collaborated with their peers to find solutions to their problems, while displaying determination, resilience and persistence to complete their project.

In addition, the two classroom assessments completed by Mr Sapsed revealed subtle improvements in the five outcomes of Science, especially in indicator 4 (present data as evidence in developing explanations). As he pointed out not only did the use of the technology stimulate the growth of the said outcomes, but also made the assessment possible, because without access to STEM technology evaluating students' progress in coding and programming is "just working against yourself" to use Mr Sapsed words.

Another key observation was that working with the Inventor Robotics and the Tablet Robotics strengthened students' motivation to learn more about technology. As Chen and Lo (2019) state one of the benefits of utilising STEM technology like Makey Makey is that students become increasingly more interested in acquiring information on technology, which was captured in our study. In their reflective journals some students frequently wondered what else they could do with the equipment or if they could apply it to new contexts and situations, conveying a sense of curiosity and a genuine interest to find out more about the applicability and affordances of the technology. Their definite preference and enthusiasm for using the equipment was also exhibited in their ratings of their classroom experience with and without the technology. Year 6's rating of the STEM technology-integrated lessons was averaged at 9.07. However, a rating of 6.61 for the non-technology lesson indicated that the activity was less popular and not immediately appealing to students, highlighting the potential of the stem.T4L technology for creating a fun and engaging learning environment.

The benefits of using robotics as a pedagogical tool are well-researched and conclusively proven. From the development of 21st century skills such as problem solving, critical thinking, communication, and teamwork (e.g. Brand et al., 2008), to STEM engagement, motivation and interest (e.g. Blotnicky et al., 2018), to gains in cognitive domains such as in computational thinking and programming (e.g. Bers et al., 2014), the impact of such technology on students is suggested to be powerful, easily discernible and long-term. In this report, we showcased some of the exciting opportunities that the integration of the stem.T4L technology presented in a Primary school setting. The positive outcomes that validated and mirrored previous studies are to incentivise teachers to channel more conscious efforts into designing STEM learning activities that incorporate STEM technology to enhance teaching and learning experiences.

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