stem.T4L

A study on the implementation of aeroponics in NSW public schools: A case study of Rozelle Public School and teacher feedback summary

In this report, findings indicated that the Aeroponics kit had cultivated experiential assembling, where students were actively engaged in their learning process and played key roles such as assembly of towers, researching, planting, PH testing, monitoring the plants growth, and packing the kit.

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EXECUTIVE SUMMARY

In Term 1 of 2023, an Aeroponics kit became available to schools as part of stem.T4L loan kit offering. A need for research was identified to explore schools' first-hand experiences of this unique technology to better understand the potential of aeroponics as a teaching and learning tool. To this end, an expression of interest was sent to the 31 schools with a booking in semester 1, among which Rozelle Public School (Rozelle PS) was nominated for a single-case study. Three classroom observations were conducted in Term 1 and Term 2, and three reflective journals were collected from students and the classroom teacher. In addition to the data obtained from Rozelle PS, an online teacher and student survey were administered at the end of Term 2, 2023. Findings indicated that the Aeroponics kit had cultivated experiential learning, where students were actively engaged in their learning process and played key roles such as assembly of towers, researching, planting, PH testing, monitoring the plants growth, and packing the kit. The technology had also provided the opportunity for students to learn about real-world issues such as environment, food, and growing, while being in control of their learning "from start to finish". Other key findings of this research included:

Key findings

- The Aeroponics kit was mainly incorporated in the Science unit, with "sustainability" and "needs of living things," at the centre of the discussions. Also, as the classroom observations revealed, one of the key affordances of the Aeroponics kits were its considerable potential for generating lively class discussions around topics such as its functionality, how it compared with other conventional growing techniques, and what advantages or limitations it had.
- The majority of teachers who took the survey rated their experience as "somewhat positive" (56%), although 33% believed the trial had been "extremely positive". In terms of the effectiveness of the Aeroponics kit for teaching STEM, 56% found the technology "very effective" and another 33% "extremely effective". The surveyed teachers described this growing technology as "marvellous, easy to assemble and use" and "something new and interesting", that had served as "talking points", and "encouraged curiosity".
- The key competencies fostered by the use of aeroponics, included "critical thinking" and "troubleshooting", followed by "collaboration/ teamwork," and "creativity and innovation."
- According to Rozelle's classroom teacher the Aeroponics kit was "highly engaging", and provided an "authentic" learning environment, wherein "students were on task and motivated", while "enthusiastic about the unit ahead".
- In their reflective journals, Rozelle PS students consistently rated their learning experiences above 7.50 out of 10. Some conveyed a renewed enthusiasm and passion for planting, and some others found the Airgarden "a great idea"; or "loved" how they "got to do something" practical, which would not happen "every day," as other students reasoned.
- The issue that the teachers identified as the main challenge revolved around "time constraints", with all teachers calling for a longer booking period of the kit. They pointed out that environmental factors such as colder weather or pests had slowed down the germination process.
- It is recommended that the booking period of the Aeroponics kit should be extended especially during the colder season for an increased chance of a better harvest. Alternatively, the provision of additional supplies such as a heater or a pest net to protect against insects and birds, might more adequately prepare teachers for a successful implementation of the kit.

BACKGROUND

Designed as an ideal solution to boost plant productivity and, in turn, food production and food security, aeroponics is a soilless growing system that has gained worldwide popularity over the last decade (Eldridge et al., 2020). In an aeroponic system plant roots are suspended in mid-air over a reservoir of nutrient solution and are sprayed with mist or fog of the water-nutrient solution inside the growth chamber[1] (McBride, 2012). As the roots are suspended inside the aeroponic compartment, they receive 100% of the oxygen and carbon dioxide required, resulting in faster growth, compared to plants grown in other conventional methods of horticulture (Ernst & Busby, 2009; Kumari & Kumar, 2019). In fact, the benefits derived from aeroponic farming technology are immense, which is why they have become a widely adopted cultivation technique in many countries (Lakhiar et al., 2020). Benefits include reduced water usage, less time and space requirement, low maintenance, seasonal independence, product consistency, higher yields and fewer food miles (Eldridge et al., 2018; Kumari & Kumar, 2019).

Although the research on aeroponics dates back to the 1920s, (Kumari & Kumar, 2019), this farming technique has rarely been utilised and studied in educational research. There are a few studies on how indoor agriculture or school gardens can support science learning (Stapleton & Meier, 2022), help students learn food-related skills and knowledge (Carlsson et al., 2016), or teach them about respect and ownership (Lautenschlager & Smith, 2007). However, research on the implementation of aeroponics in schools is still in its infancy.

The addition of the 50 Aeroponics kits to the stem.T4L family provided an opportunity for research and evaluation. Through a single-case study, we explored teachers' and students' first-hand experiences of aeroponics to understand its affordances as a teaching and learning tool for STEM education. So, in the first section of this report, we recount the lived experiences of Rozelle Public School with Aeroponics kit as they set out to discover the functionality and importance of modern farming. The second part of the report summarises the findings of the online survey, which was administered to the schools with a booking in Semester 1 (2023) and aimed to capture students' and teachers' experiences with this unique technology, their views on its effectiveness as a teaching and learning tool, and their challenges and success stories. We begin with the case study of Rozelle PS.

ROZELLE PUBLIC SCHOOL JOURNEY WITH THE AEROPONICS KIT

The data reported in this section was obtained from three classroom observations and three reflective journals provided by the classroom teacher and the students in Rozelle PS. Stage 3 students, comprising 56 boys and girls that were split into two groups, implemented the Aeroponics kit in their Agri-technology unit over Semester 1. The overall aim of the unit was to design a dish with all the produce they could grow in the Airgarden. Every Wednesday the class met and engaged in a range of learning activities, from participating in classroom discussions on the benefits and uses of aeroponics to hands-on experiences such as sowing seeds, examining seeds under the digital microscope in the kit, and transferring seedlings into the towers, as will be discussed below.

[1] *For further information on how aeroponics work please refer to the Aeroponics kit page in stem.T4L Learning Library available at* https://schoolsnsw.sharepoint.com/sites/STEMShareLibrary/SitePages/Aeroponics-kit.aspx

First observation

Class discussions

One of the key affordances of the Aeroponics kit, as observed through classroom observations was its considerable potential for generating lively class discussions. For instance, a key topic for discussion in the early stages was the types of fruits and vegetables to grow. Knowing that the two towers could fit 60 plants, students had collectively decided to sow seeds such as broccoli, spinach, strawberries, lettuce, and peas.

In addition, ample opportunities existed for reflections on self/family prior gardening experiences and sharing one's stories with the class (Example: "My neighbour has planted a tomato tree on the side of the road, and it is overlapping the whole street"). The aeroponic technology also prompted ongoing discussions around how it worked, how it compared with other conventional growing techniques, and what advantages or limitations it had. The data collected from the observations highlighted Year 5s' active participation in the discussions, and their "cognitive engagement", characterised in terms of concentration, seeking information, explaining, reasoning, verbalising thinking, contributing ideas, and answering teachers' questions (Helme & Clarke, 2001), as shown in the pictures and the snippets of conversation below.

Teacher Q1: *Technology is designed to make things easier and that is why we have the Airgarden. It's been designed to solve our problems. What problems do you think it might solve? Remember we know that there is no dirt.*

Student 1: *There is no digging.*

Teacher: *Yes, we do not need tools like shovels or spades.*

Student 2: *We do not need to go outside.*

Teacher: *Yes, we do not need to go outside with our hat on and sunscreen and all that, because we are going to be inside.*

Student 3: *It is going to be cleaner.*

Student 4: *It can fit multiple plants.*

Teacher Q2: *What about its shape? Where do we put it?*

Student 2: *Maybe near the window where it gets sunlight and shade.*

Teacher Q3: *We have to put certain nutrients into the water. Where do plants generally get their nutrients from?*

Student 5: *From the soil?*

Student 3: *You said that you do not put soil in the Airgarden, but do you have to put something in the water, so the plants get their nutrients? Discussion continues.*

Student 7: *Does each plant need a different type of nutrients? Discussion continues.*

Sowing the seeds

The second half of the first lesson was hands-on, minds-on experiential learning, where students were guided to find key information in the Airgarden manual (i.e., the right number of seeds per plant), and then sow the seeds that they had already purchased, in the grow plugs. Upon checking the manual, students learned that the number of seeds was determined by plant type. For instance, they needed 2-6 seeds per plug for lettuces, and for larger fruiting vegetables such as cucumber and tomatoes, 1-2 seeds per plug was enough. Once they identified the required number of seeds for their plant, as the following excerpt shows, students were instructed to punch a small hole in the grow plug, put the right number of seeds in the hole, and then recover the coir they had removed to cover the seeds, as described on page 13 of the user manual.

Teacher: *Can you tell me how many tomatoes seeds we need to put in there?*

Student 1: *1 or 2 seeds?*

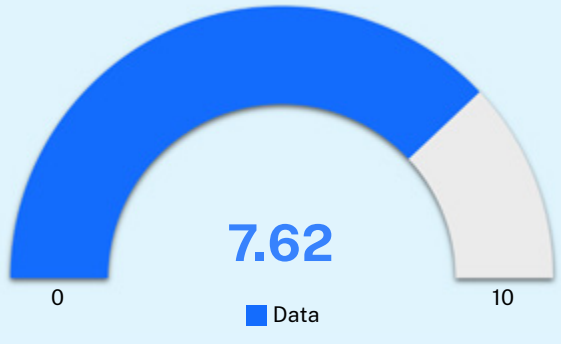
Teacher: *That is right! So, I am going to ask you to pop just 2 seeds in the plug.*

A practical tip for students to follow was to label each grow plug so that they could remember what seedlings they were when they sprouted. So, they took turns and labelled their grow plug after sowing the seeds.

The first lesson was a success; not only did the students plant the seeds and label the grow plugs successfully, but thoroughly enjoyed their gardening experience. They rated the lesson at 7.62 out of 10, and most found it a “fun” and “interesting” experience; “a great idea”; or as one student pointed out they wished they could “do more like this”. Some students voiced their new-found enthusiasm and passion for planting, and some others “loved” how they “got to do something” practical, which would not happen “every day,”. The examples below outline the reasons why they enjoyed the lesson and gave it a high rating.

- I loved doing the Airgarden and I think that this was one of my favourite lessons so far. It’s not every day you will get to do this.
- I loved how we got to do some things and it wasn’t just the teachers and I also really enjoy gardening!
- I have always enjoyed gardening and learning about nature, this for me is making me feel connected easily.
- I am passionate about planting more plants.
- I loved this lesson on Airgarden, planting the plants was a lot of fun.
- The reason I chose this score was because I found the lesson really fun, and I hope to do more like this!
- I think it’s a great idea.

- I enjoyed this lesson because it was very interesting and fun. I liked planting the plants and listening to the teacher for interesting facts.
- I thought it was really fun planting and learning all about the seeds.
- It’s pretty cool being able to grow our own stuff.
- Planting is more fun than I thought.
- That air gardens are amazing and very interesting to learn about in school and class.



Students' rating of their first lesson on aeroponics

The initial discussions had sparked student interest and curiosity about this growing technique. When prompted to reflect on the first lesson on aeroponics and share their thoughts about this technology, students raised intriguing questions, indicating that their keen and inquisitive minds were eager to understand how the produce of the Airgarden would taste, why was it even called aeroponics, and how plants could grow without soil, as the examples show:

- Why it's called an air garden?
- Is Airgarden going to be the future of growing plants?
- How does the plants grow with no soil and being inside?
- How is it going to taste?
- If growing one strawberry in an Airgarden will taste different to one strawberry grown in soil.
- Why can't you use soil in the air garden?
- Why are the kits called what they're called?
- Does the plant taste the same as soil plants?

In addition, students appeared to develop a sound knowledge and understanding of the Airgarden features and functions. They had begun to realise that this method was substantially different from any other cultivation methods, in that "plans do not need dirt," and they grow from the grow plugs, or borrowing some students' terms "in coconuts" or "coconut husk." In their journals, they confidently shared what they had learned about the Airgarden, seeds, their different colours, and the quantity needed per plug, as the examples show:

- Plants don't need dirt to survive they can have a different source.
- Not all plants are grown from the ground.
- I know what an aeroponics is.
- Aeroponics uses no soil and instead it uses coconut.
- Sometimes plants do not need to grow in soil. In fact, sometimes they grow in coconuts!
- Naturally, big plants can actually be formed and grown in a small space with nutrients from the water!
- Today, I learned that you can easily plant without a YouTube video because it is easy to learn.
- I learned how to plant seeds.
- Cucumber seeds are blue.
- Today I learned that the plants didn't contain soil instead you have to add the water with nutrients because the soil doesn't have nutrients.
- I learnt that you have to put a certain amount of seeds in the plug for each plant.
- I learnt how all types of seeds are planted and how many seeds per plant I thought it was really interesting.
- I got to plant strawberries which are my favourite fruit and learned things about the Airgarden I didn't know before.
- We got to plant seed in coconut husk.
- That coconut husk can be used as a soil.
- You don't always plant one seed sometimes you use *more.*
- Depending on the plant, vegetable, or fruit it might need more or less seeds.

So, how did the classroom teacher evaluate her first lesson on aeroponics? From her point of view, it was "highly engaging" and "students were on task and motivated." Acknowledging the fact that they needed "to do more of this kind of learning," as it was "a fantastic opportunity for the students," the teacher noted that gains from the first lesson on aeroponics were both behavioural as well as educational. For instance, she highlighted that students were "enthusiastic about the unit ahead" (behavioural outcome), and she was pleased to see students had raised "interesting questions" (behavioural outcome); and were "able to connect their prior understandings [and] problem solving with the technology of aeroponics" (educational outcome).

Second observation

Transferring the seedlings

The second class observation was conducted almost 4 weeks after the first one, when the seedlings had sprouted and were ready to be transferred to the Airgarden towers. But before that there were a few key tasks for students to undertake, including setting up the timer and putting in nutrients. During the previous lessons, which were not observed for this study, the teacher had explained how the nutrient solution was delivered by a pump, which dripped the nutrients back to the water reservoir. So, students were already familiar with the concepts discussed in today's lesson, and were able to contribute as indicated below:

Teacher: *Can somebody describe what is happening with the water?*

Student 1: *There is a jet that goes up and it brings water down to each layer.*

Teacher: *Yeah, to make sure there is even spread of water. And then what do the roots do? Remember the plants are clever so they only…?*

Students responding collectively: They only take what they need.

Teacher: *Yes, they only take what they need. They take the nutrients that they need. So, the water is falling past. But does the water fall all the time?*

Student 2: *Every 15 minutes?*

Teacher 2: *Yes, there is a tiny little electric device to control that time. What can we call such a device?*

Student 3: *Timer?*

Teacher 2: *Yes, we can call it a timer.*

Following a brief discussion on what a timer is, why it is needed, and why should we add nutrients to the Airgarden base reservoir, students were grouped and tasked to work collaboratively to retrieve information from the Airgarden Owner's manual on the timer and the nutrients and follow the instructions to make sure the Airgarden was ready for the seedlings.

The two girls in the picture below volunteered to have a go and set up the timer. Based on the information in the user manual, they found out that they needed to set the watering intervals according to the climate they lived in. They decided that for the "warm" climate of Rozelle, they needed to put 1 notch down and 2 notches up, which meant watering intervals of 15 minutes on and 30 minutes off.

Table 1 - Setting up your timer (the table is cited in the Airgarden Owner's Manual)

Average daily temperature	On (notch down)	Off (notch up)
Hot : Above 35°C	15 mins (1 down)	15 mins (1 up)
Warm : Between 15°c - 35°c	15 mins (1 down)	30 mins (2 up)
Cold: Below 15°c	15 mins (1 down)	45 mins (3 up)

The next task was to determine how much of Part 1 and Part 2 solution nutrients was required. The teacher reminding students that the nutrients were plants' "healthy food," asked them to read the user guide to learn about the quantities needed. They quickly found out that 190-200 ml of Part 1 and the same quantity of Part 2 solution should be added using a measuring cup. As the pictures below depict, students were bubbling with excitement, putting their hands up to pour the nutrients into the cup, and then to the Airgarden base reservoir. They also took a tip from the teacher on how to smell like a "scientist" and could not wait to smell the nutrients like scientists would do.

Now that the Airgarden was ready to welcome the seedlings, students' next task was to transfer the seedlings. The seedlings had germinated, although some faster than others, but once they were placed into the planting sites in the towers, they would continue their growth from there.

Teacher: *Now, everyone get a cup and a seedling! Said the teacher while holding up a grow cup and outlining the procedure for placing the seedlings into it:*

Teacher: *The seedlings need to be pushed all the way to the bottom, because when the cup goes into the tower, it's going to go down on an angle. It's not going to go straight down, it is going to go down on an angle and the water that is dripping down hits this bottom, so we need the roots to be down there. We need to make sure the roots are sticking outside.*

That was the first key point students had to remember when placing the seedlings into a grow cup. But the Airgarden had three levels; a top level, a middle level, and a lower level. So, how could students determine where to place the grow cups? Would it make a difference where the seedlings go? Putting the question to the students and sparking their sense of curiosity, the teacher provided further elaboration:

Teacher: *In the Airgarden we have got different levels that we need to put things on. Like cucumbers are going to go on the lower level. But we gotta have a look and think about why certain plant are planted on different levels.*

Student 1: *Is it because some need more water?*

Teacher: *I do not know. That is going to be your thinking challenge for today. I have a sort of diagram that shows the plants that should be planted on the bottom etc. you can use laptops to do some research. Think about what is common about all those plants and why they have been positioned where they have been positioned.*

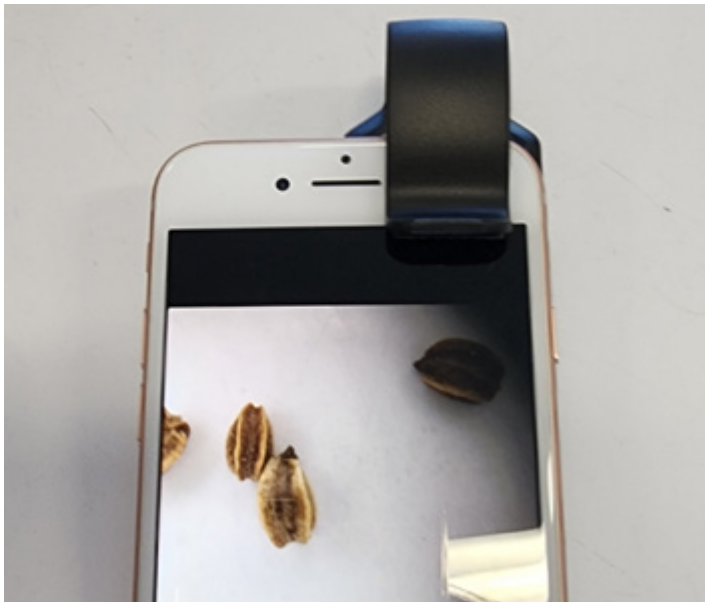
A few students jumped online to search for answers, others looked for information in the user manual. Soon, they found out that plants that grow upward should be placed in the top layer, the second or middle layer was for medium sized plants that stayed compact, and the larger, or vining plants that took longer to grow belonged to the bottom layer.

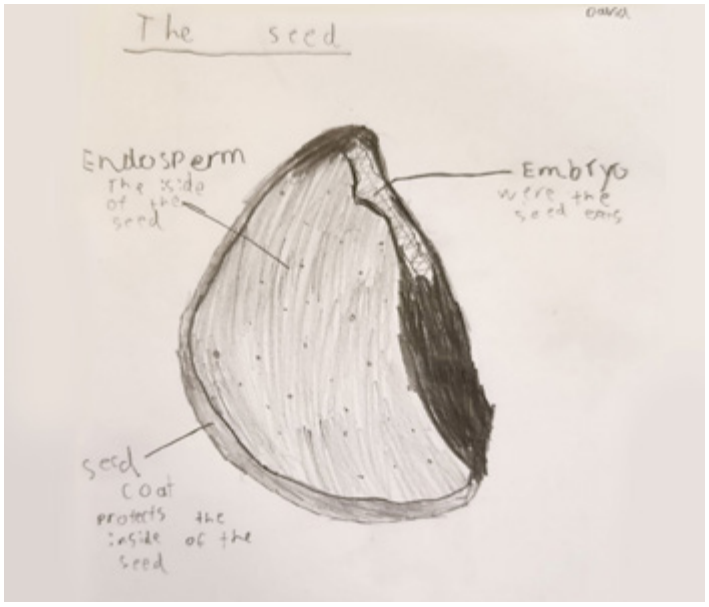
At this stage, students had all the pieces of the puzzle— they had set up the timer, put in the right quantity of the nutrients, placed the seedlings into the grow cups, and knew exactly in which level of the towers each grow cup should be planted. So, to complete the final stage, students lined up and one by one transferred their seedlings in to the Airgarden tower.

Seeds under a digital microscope

The second learning activity conducted in conjunction with the transfer of seedlings was to examine seeds structure under the digital microscopes. The Aeroponics kits come with 10 digital microscopes and 10 iPhones, providing further opportunities for hands-on learning and collaboration to facilitate effective engagement. Unlike normal microscopes, digital microscopes are connected to a computer or phone and, hence, have the ability to save and manipulate the images. That is why they are powerful tools in the classroom to teach students skills like observation, awareness, order and organisation, and analysis (Jones, 2008).

One way to benefit from the digital microscopes in the aeroponics lessons is to examine the selected seeds and identify their structure and component parts. Starting off with a video tutorial that demonstrated the three parts of a typical seed, students were instructed to capture images of a seed under the microscope, and draw a diagram based on their observations. In their first attempt at using the microscope some students struggled to capture a perfect image, as they mentioned in their journal (e.g., *"I found it hard to zoom in on the tiny seeds because it started out blurry;" "I found it challenging to zoom in with the microscopes."*) Yet, motivated by the collaborative process, which was facilitated by the teacher's instructions, students were able to adjust the resolution and magnification and took clear pictures:



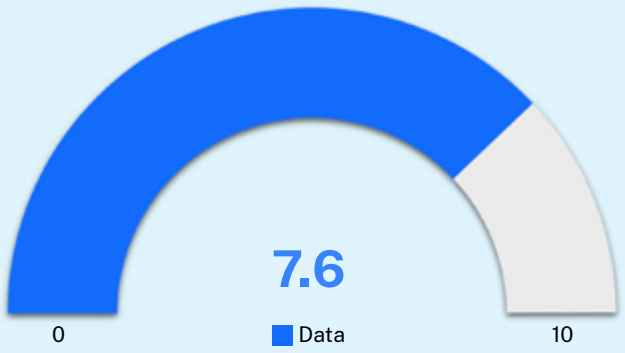


The learning activity was “fun” according to the students, and they were fascinated by how the seeds looked under magnification, as indicated in the examples below from their second reflection. Also, the hands-on and exploratory nature of the activity, which had made the learning more meaningful to students, had a clear positive effect on their retention and understanding of the three parts of the seeds (i.e., Coat, Endosperm and Embry), suggested in their ability to accurately draw a diagram and identify the parts of a seed (example above).

- It was fun and I have never done something like this before.
- Amazed what the seeds looked like.
- I liked that it was interactive and that we got to use a microscope.

- In the first activity with the microscopes, it was so cool-like you were in a whole different world.
- I liked using the microscope and looking at the seeds.

The second lesson received another high rating at 7.60, with students writing favourable comments on the lesson. In response to the question “how did you feel when participating in today’s activities?” most said that they had “loved” the activities, or were “excited” or “happy,” when engaging in those activities. Some had even felt “achieved,” “amazing,” or “proud,” that they “could plant the seed without failing”:



Students’ rating of the second lesson on aeroponics

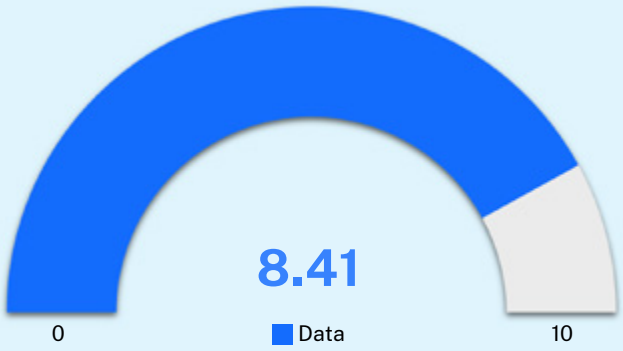
- Loved how we did the plants and the liquid that we poured in the aeroponics’, today was amazing I'm glad that we did this.
- I loved planting the seeds and learning information.
- I enjoyed this lesson because I got to plant stuff.

Third observation

Harvest day

The final classroom observation was carried out on the harvest day, when the produce had fully grown to become part of a dish that the students had planned. Year 5 had grown plenty of leafy greens including lettuce, coriander, and spinach, while they still had other plants that clearly needed more time to develop. So, in order to give students the full experience of designing a dish, the teacher had purchased additional vegetables and fruits like cucumber, carrot, avocado, lemon and strawberries, beforehand, and set up a table with all the items students needed in order to make a dish, a dip, or a salad. The following pictures demonstrate students working in groups, charged with excitement to first harvest the produce, and then design their dish with the available ingredients.

The journey that had started with sowing seeds in the "coconut husk" (i.e. grow plugs) culminated with a joyous celebration of the produce grown in aeroponics, which was then fully consumed by students. They rated this experience exceptionally high at 8.41; some stating that "cooking with friends" was the best part, and others wishing they could have the kit for a longer time. But as the comments below show the majority of students acknowledged that now they knew *"how the plants can grow,"* and they had learned a lot from this experience or had *"expanded [their] plant knowledge by a mile".*

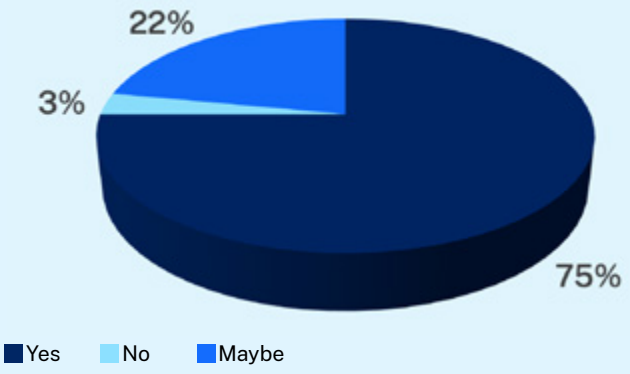


Students' rating of their final lesson on aeroponics

- I loved growing the plants in the Aeroponics kit. It was so fun and entertaining! I loved cooking dishes, and they tasted so good and fresh! Although sometimes I found some lessons more interesting than others.
- I liked the Aeroponics kit because I enjoy learning about plants and how they grow. The downside was we didn't get long enough with the Aeroponics kit.
- I liked that we can grow plants and food and I liked when we put the seeds under the microscope.
- I liked it because we got to learn about plants and that we got to make food.
- I would of liked if we had more time to watch them grow and more time to make our dishes.
- I really liked planting the seeds, but my very favourite thing was making the food it was sooooo much fun.
- I loved it because I like planting, and making the dish at the end was the best because I like making food at home and it was even better here. But there are a lot of other things I like so I gave it an 8.
- I liked the Aeroponics kit because I enjoyed learning about how the plants can grow while in the Aeroponics kit.
- I loved doing it with my friends. It was fun making a salad.
- It has expanded my plant knowledge by a mile.
- I think it was wonderful and I thought this is a great opportunity for people learning about plants.

As a final question, we explored students' ideas about the importance of implementing the Aeroponics kit and whether all students should have the opportunity to learn about this growing technique. Undoubtedly, aeroponics had left a favourable impression on the students, as 75% confirmed that having such equipment in school was "very important". They reasoned that it not only gives students a *"fun"* experience that could show them *"how amazingly plants can grow,"* but they get to *"get hands-on work"*, learn to *"take care of the plants"*, and be *"independent"* and *"confident"*, as the examples below suggest:

Table 2- Should all kids learn about aeroponics in school? Students' views



- It's fun to teach kids how to take care of plants.
- It gives them self-confidence and teaches them how to be independent.
- So they can plant their own plants at home.
- Kids should learn how to grow plants and have hands on activities like these.
- It's very important for children to learn about how amazingly plants can grow and how interesting it was learning about the Aeroponics kit.
- It's very important because the Aeroponics kit is a very unique way of growing plants.
- I think it is a good time to get hands on work like gardening and looking at plants.
- Because it was fun and educational for others and myself.

Similarly, the classroom teacher, in her final reflection, considered the overall experience "extremely positive," where she highlighted that the integration of the kit in the Technology and agri-technology unit was "extremely effective" for teaching STEM. She pointed out that throughout the Airgarden lessons "teamwork," "collaboration," and "engagement" hit a new high, and the kit offered an "authentic" learning environment for students. Clearly, students' lively interest and curiosity to learn more about this unique technology had spread far and wide, as the school leadership group had become motivated *to purchase two Aeroponics kits for the school*, as the teacher told us:

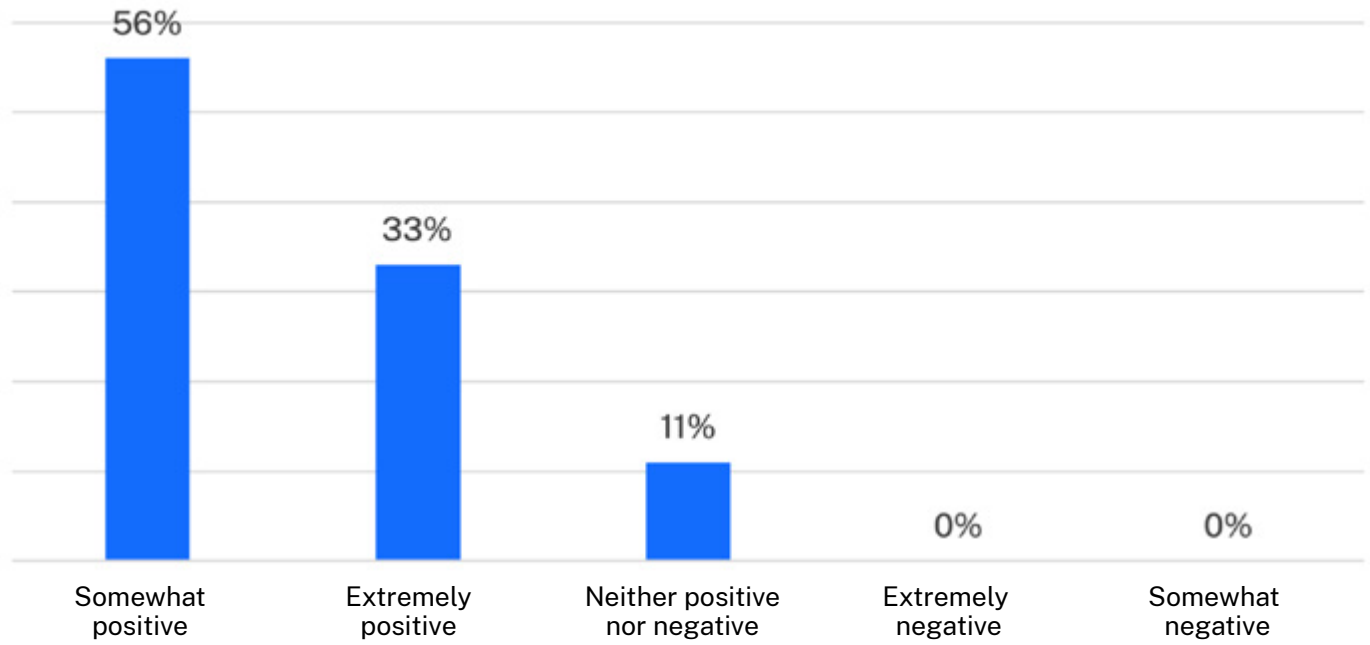
- The students were really interested in the way that it works, the problems that this type of growing solves and all of the things that we could do with the produce. We now have two of our own.

However, a criticism that was voiced by the teacher, and the biggest challenge, concerned the duration of the trial. Being winter, she argued, had affected the growth of the plants and they needed more time with the kit to see better outcomes. This concern was also raised by other teachers who participated in the aeroponics survey. 10 teachers completed the online survey, administered at the end of the Term 2. Below we will have a quick look at their feedback and comments on their experience.

TEACHER FEEDBACK

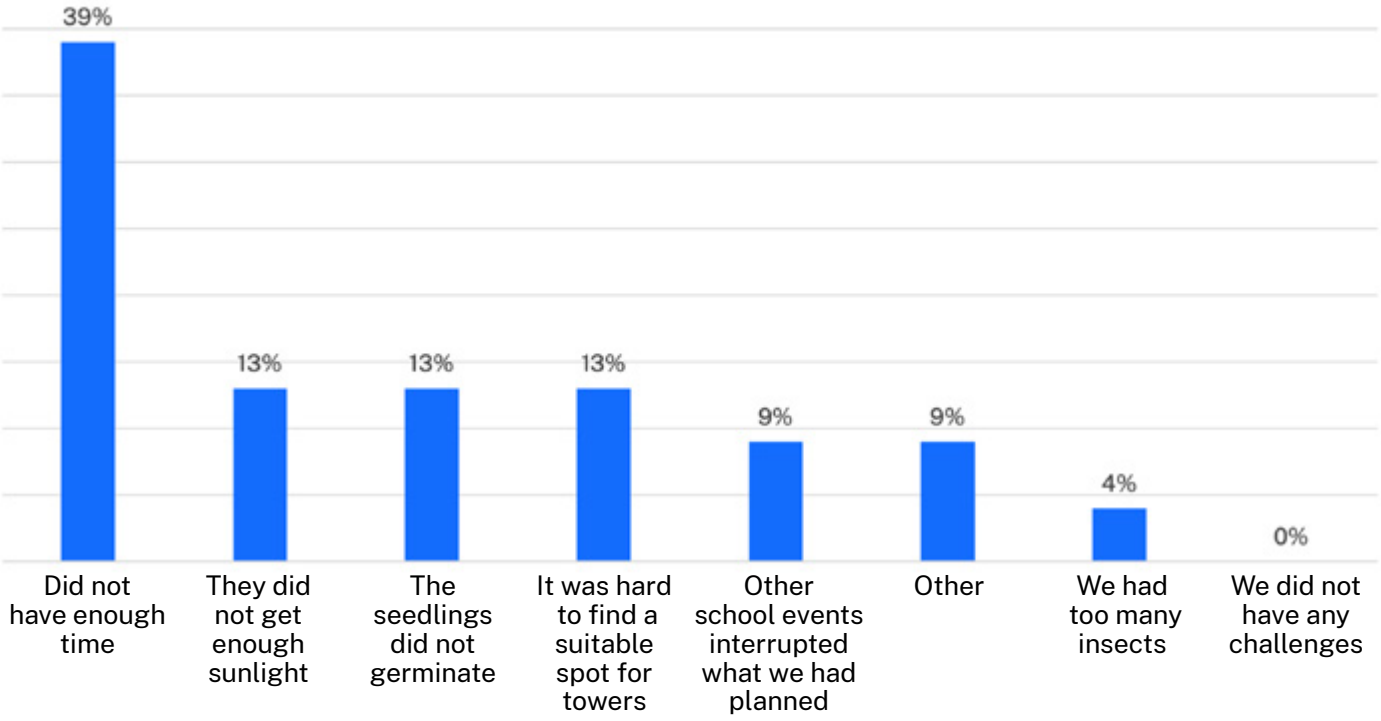
From the 31 schools that had received the teacher survey on the effectiveness of the Aeroponics kit as a teaching and learning tool, 10 primary school teachers (7 females & 3 males) completed the survey, and the majority rated their experience as “somewhat positive”. Although 78% could attest to the positive impact of the Aeroponics kit on student learning, it appeared that most teachers had faced several challenges throughout the course of this experience, as will be explained below.

Table 3 - Teaching experience with the Aeroponics kit



Challenges and hiccups in using aeroponics

Table 4 - Challenges and hiccups



As Table 4 suggests, “time limitations” topped the list, with all the primary teachers. They maintained that they could have achieved more satisfactory outcomes if they had kept the kit for a longer time. Also, a few teachers pointed out that the colder weather had slowed the germination process, hence the need for extending the kits booking period — a factor which should be taken into account moving forward for efficient implementation of the equipment. Examples from teachers’ commentaries are provided below:

- Some seedlings didn't germinate - we had enough for one tower. Not enough time for them to produce fruit.
- The kits didn’t arrive until the end of Week 8 so we didn’t have as much time as we would of liked with them. We didn’t really use them we more looked at what was inside and how they could be used.
- There were excellent resources etc however time was a big issue. By the time we got the kit and then put seeds in the plugs it was the second last week of term. Some of the learning regarding germination is an issue as the holidays came and then they have to be looked after in the holidays (my general assistant forgot to water so they died, and I had to start again in the first week of term). It is winter so they took longer than they would in summer to germinate and be big enough to put in the Airgarden. It was really only in about week 6 we started to see dramatic growth and we could compare but with 10 classes it is tricky to get them all to see and use the Microscopes/Microbits etc. It is a great tool and would teach the kids so much, but I actually think one term is not long enough.

In addition, small hiccups such as wildlife feasting on the seedlings, plants not having enough exposure to sunlight, or the grow plugs being “sealed” at the bottom, were “other” problems that the teachers reported. As such, it was found that 70% of the schools were not able to harvest all the seeds they had initially planted. The teachers told us that they had either replanted seedlings in the school garden or the plants *“were sent home with students to keep growing.”*

- We had a lot of insects on ours towards the end.
- We also had problems with location. I couldn't put the garden in a spot that was close to power and also in lots of sunlight. I had to move the garden inside each night- which was a challenge in itself as it's very heavy to move.
- Local wildlife helped themselves to the seedlings, which delayed the process by 2-3 weeks.
- Some of the grow pods were "sealed" at the bottom so the tap roots had to work really hard to get through - some did not make it. :(I would suggest (maybe it was in there and I didn't notice?) making a significant hole in the bottom of the grow pod to allow the roots to exit down.

Benefits and impact

Moving on to the achievements obtained and the positive impact of this experience, firstly we found that the majority of teachers had incorporated the Aeroponics kit in their science unit, with “Sustainability” and “Needs of living things,” at the centre of the discussions. Clearly the stem.T4L resources available in the Learning Library had become teachers’ go-to guide and had provided a reference point for them when creating teaching plans and structuring lesson ideas (Table 6). Adopting a participatory learning approach, where students were actively “*involved from start to finish,*” the teachers also told us that they had allocated key roles and responsibilities to students from assembly of towers, researching, planting, pH testing, monitoring the plants growth, to packing the kit (see comments below).

Table 5 - Main focus of lessons on aeroponics

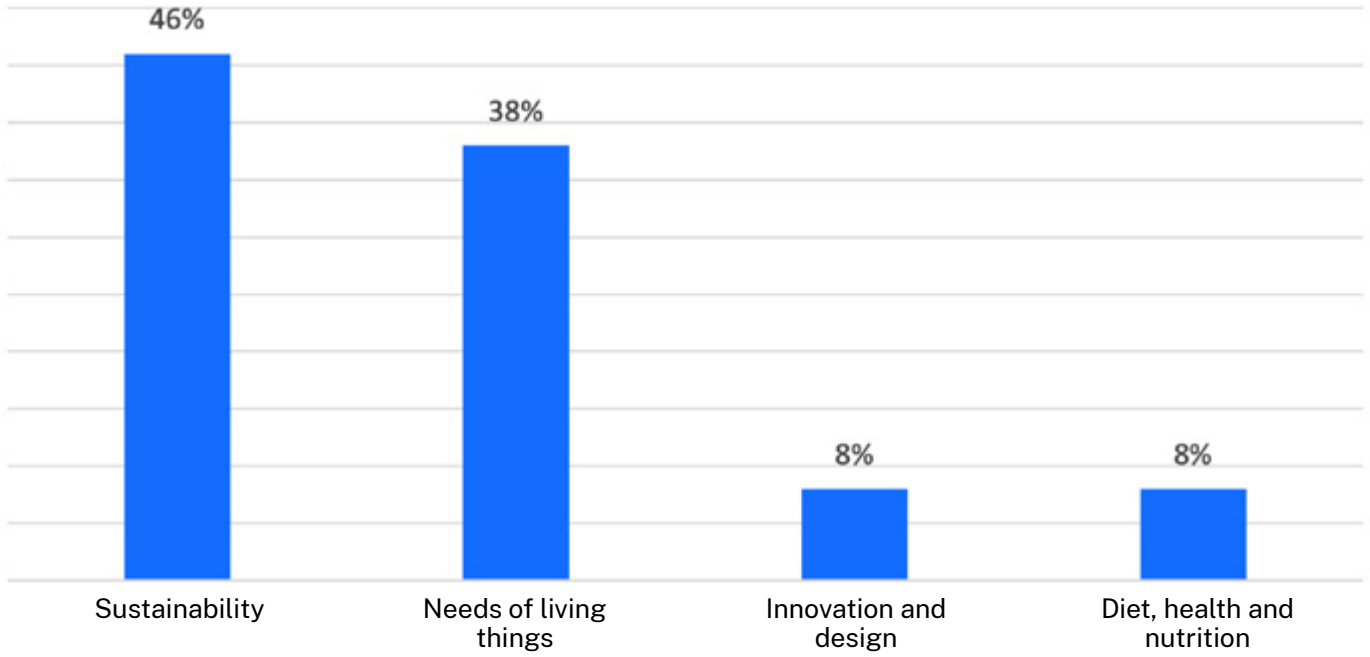
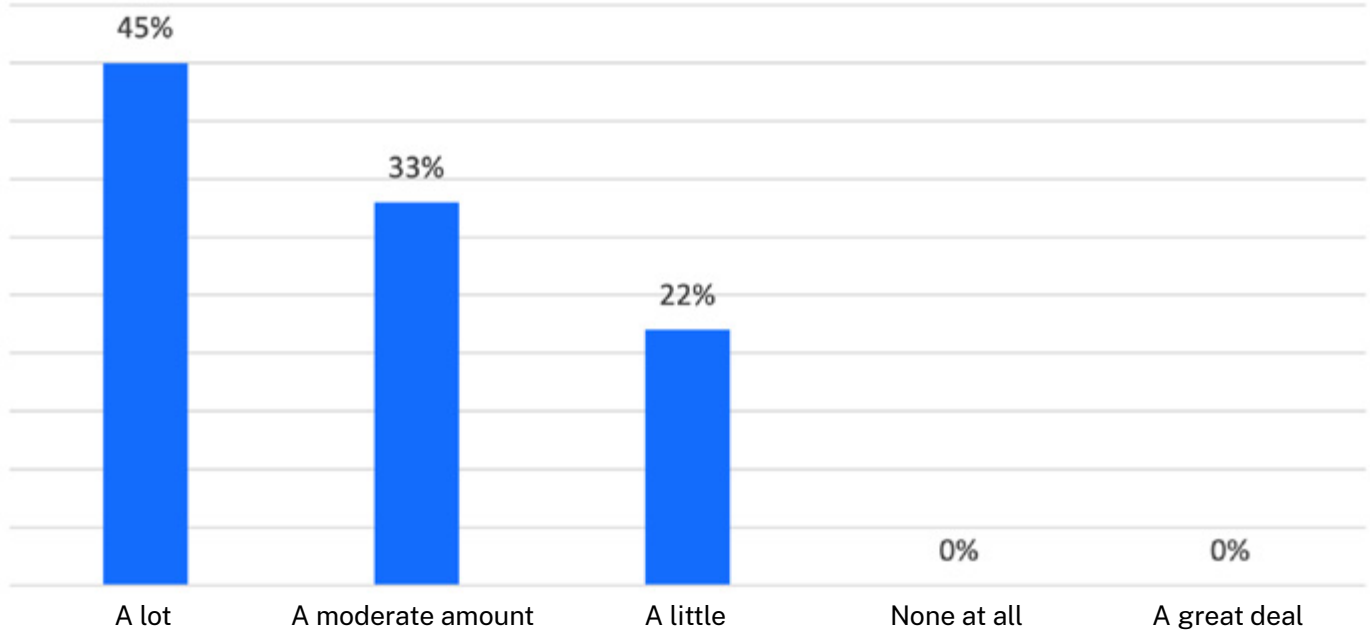


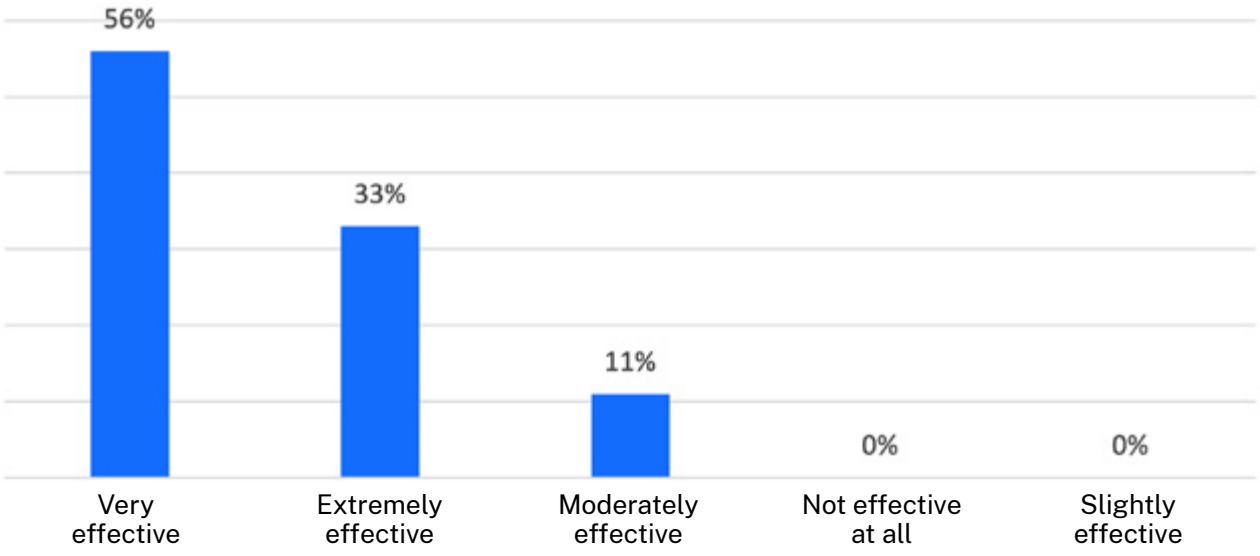
Table 6 - Teachers’ use of the stem.T4L learning library



- Testing ph levels, plant growth, refilling the tank etc.
- Assembly of towers, checking of pH levels, selection of seeds harvesting.
- They were involved from start to finish, unpacking to cleaning and packing and everything in between. The students researched and selected the plants that were to be grown, and also contacted local nurseries and Bunnings to have the seeds donated. They were responsible for maintaining the Airgarden through the whole process.
- They helped to plant, put together, water, and check on the plants.
- Students planted the seeds, drew diagrams of the plants, and watered the comparison plants and seedlings. We have a dedicated science RFF program, so the kids only get to see the towers for an hour a week - not long enough to do the whole program unfortunately. It was a talking point for all the classes that came in - even though only one class really studied it.
- Researching the best seed choices, planting seeds, watering and monitoring seeds, checking for roots etc, moving pods into garden, checking for growth, keeping the crows away!, replanting seedlings into gardens at school.
- Planting the seeds. Watering the germination trays. Checking the tower had enough water. With teacher assistance - adding nutrients and pH testing.
- Checking pH, watering plants, putting out seeds.

The Aeroponics kit had delivered tangible benefits to students through placing such a strong focus on experiential learning. Considering the kit a "very effective" (56%) or "extremely effective" (33%) tool for teaching STEM (Table 7), the teachers described the Airgarden as "*marvellous, easy to assemble and use*" and "*something new and interesting*", that had served as "*talking points*", and "*encouraged curiosity*". When asked which student competencies the use of aeroponics had fostered in particular, "critical thinking" and "troubleshooting" were at the front of teachers' mind, followed by "collaboration/teamwork," and "creativity and innovation." The commentaries further revealed that the Aeroponics kit had not only provided "*authentic, highly engaging learning*" to "*ALL students,*" but they had allowed students to do "*Science in a real life setting,*" while having "*control over the process,*" to learn about "*different way of producing food*" and "*the life cycle of plants.*"

Table 7 - To what extent is the Aeroponics kit an effective tool for teaching STEM?



- Students certainly understood the role of photosynthesis more clearly (we didn't have enough sunlight for the plants).

- It allowed ALL students to be engaged.

- Talking and listening - lots of discussion based around the growth cycle. Science - life cycles maths – measurement.

- Understanding of sustainable practices. Growing the curiosity of the students.

- I just think it's great to have a variety of learning experiences that the students can have a go at. I have booked kits every semester so far and absolutely love them. Sometimes we may not use them as intended, but they always provide talking points, encourage curiosity, and foster critical and creative thinking. Win all around.

- One of the skills they did learn was to take detailed photos and label them digitally - some kids of course were already good at this, but not all. Transferring the photos to a diagram in their books also proved challenging for some, but we got there.

- Something new and interesting that the students haven't seen before.

- Students could watch plants grow from seeds to mature in a short space of time. They felt that they had control over the process.

- Given we are an inner-city school, where many students are not used to having gardens at home, this provided them with a real life example of the life cycle of plants. Students of all ages loved it. I initially thought the garden would be ideal for us, but having tried it, I have realised out school environment is not suitable. Thanks for giving us the chance to test out equipment and projects like this. We love it!

- Just to show the students a different way of producing food. The kits are marvellous, easy to assemble and use. Kids loved the microscopes.

CONCLUDING REMARKS

The data obtained from Rozelle PS and the teacher survey indicated that students had gone through an iterative learning cycle from start to finish; each phase creating abundant opportunities for active participation in multi-layered learning about real-world issues such as environment, food, and growing. The skills and learning that had been reinforced or emerged during this experience included negotiating the types of seed to plant; scheduling and planning; researching, transplanting seedlings, monitoring the growth cycle, and nurturing the plants, utilising digital microscopes to study seeds, and harvesting the produce to consume. In each stage students were engaged in a collective effort to explore the unknown and make sense of their learning through discussions, reflection on prior experiences, critical thinking, and problem-solving.

Although the findings of this case study were limited by the number of teacher and student survey responses, they have key implications for the project. Apart from the positive outcomes drawn from the study, the findings illustrate that additional measures need to be introduced to maximise the efficiency and potential of the Aeroponics kit. As the germination and growth of plants, hence the eventual success of the experience, is partially determined by environmental conditions such as climate and pests, teachers with the kit should not hesitate to get started as soon as it arrives and work with students to be proactive throughout their growing journey!

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