# Improving Students' 21st century skills through the stem.T4L Project

This research is an investigation into the development of students' 21st century capabilities and teachers' STEM competence and confidence during their involvement in the stem.T4L Project in Term 1.

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The stem.T4L Project was formerly known as STEMShare Community

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## EXECUTIVE SUMMARY

Extensive research has been conducted on the stem.T4L Project since its launch in 2018, in order to measure the impact and implications of the project. So far, a total of 987 teachers and 6,350 students (Years 4-12) have generously contributed to the research by completing one or both of online surveys administered at the beginning and end of each school term. Term 4 (2018) research indicated a major boost in students' and teachers' STEM self-efficacy beliefs, leading to a more positive attitude to STEM. Also, the remarkably high satisfaction rate suggested the project had a considerable success in Term 4.

Term 1 (2019) research focused on students' 21st century skills and explored the contribution of the stem.T4L Project on development of students' 21st century capabilities. It also delved into teachers' STEM confidence and competence, and measured the overall effectiveness of stem.T4L professional learning programs in equipping teachers with the right knowledge and skills to apply STEM technology. In total, 150 teachers (21.33% Male & 78.67% Female) and 799 students (52% Male & 48% Female) took the pre and post online surveys sent to schools at the outset and end of Term 1. The majority of the participating teachers were primary teachers (86%), with an average knowledge of technology and a noticeably low STEM self-efficacy. However, the findings revealed a considerable boost in teachers' STEM self-efficacy.

The key findings from this research are as follows:

- ✓ At the outset of Term 1, teachers' STEM self-efficacy was found to be at 3.68, meaning 40% of teachers were not confident to teach STEM. The average score improved to 4.00, with 79% feeling confident to teach STEM at the conclusion of the project.
- ✓ 79% of teachers who participated in the research undertook one or more of stem.T4L professional learning programs, 88% of which had high satisfaction with their experience. However, 20% of teachers did not make use of PL opportunities as they were not aware of stem.T4L professional learning programs, were time poor, or had enough prior knowledge.
- ✓ The main factor contributing to teachers' sense of readiness to implement STEM technology, as indicated by teachers, was stem.T4L professional learning. Other factors included school climate, teachers' own knowledge, confidence and passion, and students' active participation.
- ✓ How-to-videos (36.30%) and Learning Library resources (29.79%) were the most highly used form of PL, while participation in face-to-face events was slightly low (17.81%).
- ✓ Teacher collaboration improved from 2.84 (34%) in Pilot to 3.11 (40%) in Term 1, as teachers exchanged ideas and practices through social media. Sharing stem.T4L equipment also facilitated teacher collaboration as it provided teachers with the opportunity to visit neighbouring schools, team teach, and offer support.
- ✓ One of the main sources of frustration and dissatisfaction with stem.T4L equipment was found to be technical challenges. Also, 10% of students pointed out that they used stem.T4L equipment "only once" because of technical issues.
- ✓ Overall, 78% of teachers participating in the research were promoters of the project.
- ✓ The mean scores of students' self-perceived 21st century skills improved from pre to post evaluation. One reason for this increase could be the highly interactive environment that the stem.T4L Project cultivated.
- ✓ Girls' STEM self-efficacy did not change from before to after the implementation, neither did their attitude towards STEM change.

## INTRODUCTION

In today's world, student mastery of the 3 R skills (Reading, wRiting & aRithmetic) is not the main concern of the education system (Husin et al., 2016), rather developing a set of competencies and higher-order skills in students to empower them to successfully surmount the challenges of the complex world. These capabilities are commonly called 21st century skills (other terms used are 'non-cognitive skills', 'soft skills', 'dispositions', and 'attributes'). They include: problem solving; critical thinking, creative thinking; communication; social skills and teamwork; and leadership.

Much has been said about why students should be equipped with these skills. For instance, some argue that 21st century skills have a pronounced and long lasting effect on different aspects of students' lives (Kautz, Heckman, Diris, Weel, & Borghans, 2014), as they improve student ability to learn (Bjorklund-Young, 2016). More specifically, these skills create "lifelong learners who are confident, connected, and actively involved in education, society and culture" (Lucas & Smith, 2018 p. 4). Others discuss that the 21st century skills are demanded by the workforce and individuals with "enterprise skills" (such as problem solving, communication and team work) have a higher chance in landing full-time jobs (Foundation for Young Australians, 2018, cited in Lucas & Smith, 2018). In fact, the essence of 21st century skills is an emphasis on "what students can do with knowledge, rather than what units of knowledge they have" (Silva, 2008 p.2). Hence, students who are problem-solvers can work independently, take initiative, and are not afraid to fail – the skills employers are looking for (World Economic Forum, 2016). Interestingly, some researchers also believe the acquisition of skills such as problem solving and creativity can assist in students' STEM (Science, Technology, Engineering, and Mathematics) development. For instance, some researchers found that 87% of girls interested in STEM also showed an interest in problem solving (Modi, Schoenberg & Salmond, 2012), suggesting a close link between STEM and problem-solving skills.

In line with the growing emphasis on cultivating students' 21st century skills and making education more pertinent to 21st century learners, researchers and educationalists have recently shifted their attention from *why* to teach the capabilities to *how* to teach them (Scoular & Care, 2018). To this end, measures have been taken to include skills such as critical thinking, problem-solving, collaboration, and creativity in the curriculum materials (Scoular, 2018) and assess these skills to capture how they are developed (Lamb, Jackson, & Rumberger, 2015). Reports show that 86% of countries include these capabilities in documents governing education systems, while 55% feature them in curriculum documents and 12% describe progression of the 21st century skills across age and subject groups (Care, Kim, Anderson, & Gustafsson-Wright, 2017). Along with the inclusion of the capabilities in curriculum, effective pedagogical approaches have been employed to create authentic learning environments that can boost students' 21st century skills. Problem-based, Inquiry-based, and Project-based Learning are some of the most widely used methods (Cooper & Heaverlo, 2013; Hmelo-Silver, 2004; Zhao, 2012). Through problem-based learning, for instance, students draw upon a set of cognitive and social skills to define the problem, employ useful strategies, and find the best solution to address the problem (Scoular, 2018). Another approach to enhance 21st century skills is implementation of robotics in education (Brand, Collver, & Kasarda, 2008). Robotics engage students in team work interactions and collaborations, and introduce challenging problems that can help students tap into higher order thinking skills, creativity, and problem solving.

Now the question is: what is Australia's stand on capabilities and what approaches have been taken to foster these skills? According to Lucas and Smith (2018) there are five signs that show Australia is aligned with the worldwide shift to inclusion of these skills. For instance, Australia has included capabilities in the core national documents governing education, and developed new capability frameworks across national and state borders. Also, there appears to be more participation of different stakeholders in the conversation. As such, Lucas and Smith (2018) conclude that the Australian education system "is well placed to promote capabilities from the early years, through senior secondary schooling, and in post-school contexts" (p. 3).

Given the increasing emphasis placed on the development of 21st century skills within the Australian curriculum, it is critical to understand how the stem.T4L Project could contribute to the advancement of 21st century skills. stem.T4L Project as a new initiative that draws upon robotics and educational kits (e.g. virtual reality, 3D printing, and filming kits) was launched in NSW in 2018. The objectives of this project are multifaceted and include "raising awareness of effective use of technology to improve student learning, and supporting student capability to use technologies for learning and to build digital resilience". To this end, research has been conducted on different aspects of the project since its launch to measure the impact of the project and to benchmark the outcomes against the goals (please see previous reports on stem.T4L Project). For instance, research carried out in Term 4 (2018) showed that implementation of the stem.T4L equipment enhanced students' and teachers' STEM self-efficacy. The contribution of this project to advancement of students' 21st century skills was briefly explored in previous research as well. However, in the present study we delved more deeply into the role of the stem.T4L Project in enhancing such skills. Also, given the significant role of teacher STEM self-efficacy in successful implementation of the stem.T4L equipment, further examination was conducted on this variable to be able to compare results across the entire research cycle and draw implications from the research. The research questions raised in the present research were:

## 1.1 RESEARCH QUESTIONS

To what extent did the stem.T4L Project enhance students' self-perceived 21st century skills?

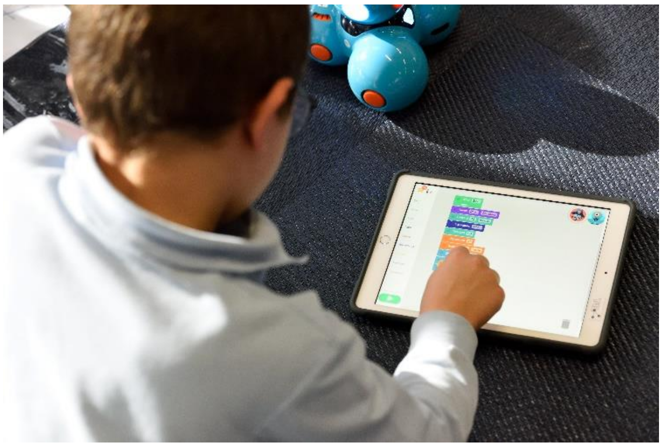
Were there any changes in teachers' STEM self-efficacy beliefs from before to after implementation of the program?

To what extent did girls' STEM self-efficacy and attitude improve after implementation?

## 1.2. RESEARCH DESIGN AND PARTICIPANTS

A pre-test/post-test design was used to assess the degree of change or improvement over the course of Term 1. Pre-test/Post-test is by far one of the most effective approaches that can pinpoint the effectiveness and success of a program (Shaha, Lewis, O'Donnell, and Brown, 2004). To measure the variables under investigation, two online surveys were designed for the two groups of respondents (i.e. teachers and Y5-12 students) and administered through Qualtrics at two time points, at the outset of Term 1 (i.e. before the respondents used the stem.T4L equipment) and at the end of Term 1. It was assumed that by completing the survey prior to using the stem.T4L kits, we would be able to have an accurate estimate of respondents' self-perceived 21$^{st}$ century skills and STEM self-efficacy without the influence of the project, which could be measured against the end of term findings.

The pre and post surveys included almost identical items and consisted of multiple choice items and open-ended questions. Using a 5-point Likert scale, the respondents could choose an option from 1 = strongly disagree to 5 = strongly agree. Open-ended items were added to the surveys to gain further information on respondents' perceptions of the stem.T4L Project and also to give respondents the opportunity to freely discuss their point of view.



In total, 152 schools participated in the pre-test surveys, with 2,151 students and 426 teachers completing the surveys. At the conclusion of Term 1, a large number of respondents who had filled out the pre-test surveys dropped out, leaving us with a response rate of almost 35% (799 students and 150 teachers). The breakdown of each respondent group in pre and post-test surveys is presented below.

| | Pre-Survey | Post-Survey |
|---|---|---|
| Student (Ys 5-12) | N=2151 | N=799 |
| | Male= 51.19% | Male=52.07% |
| | Female= 48.81% | Female=47.93% |
| | Primary=76.15%<br>Secondary= 23.85% | Primary=81.48%<br>Secondary= 18.52% |

| | Pre-Survey | Post-Survey |
|---|---|---|
| Teacher | N=426 | N=150 |
| | Male=20.19% | Male=21.33% |
| | Female=79.81% | Female=78.67% |
| | Primary teacher=82.39%<br>Secondary teacher=11.97%<br>Other=5.64% | Primary teacher=84%<br>Secondary teacher=12.67%<br>Other=3.33% |

## STUDENT SURVEY

A pre-test survey was designed for years 5 to 12 students and consisted of 24 items that measured 21st century skills. This survey was developed based on theories and prior research (e.g. Faber, Unfried, Wiebe, Corn, Townsend, 2013; Goodyer & Soysa, 2017; Szmodis & Bodzin, 2017). Using a 5-point Likert scale that ranged from 1 (strongly disagree) to 5 (strongly agree), students were prompted to self-assess their skills in 6 areas, namely Creativity and Innovation (4 items), Teamwork and Collaboration (5 items), Leadership (4 items), Problem solving (4 items), Communication (4 items), and Critical Thinking Skills (3 items). Higher agreement with the items were indicative of students' higher confidence in their abilities. In addition, one question (5 items) was raised to gauge girls' STEM competence and confidence to explore how the use of stem.T4L kits could enhance their self-efficacy beliefs. It is worth noting that this question could only be viewed by girls and the data collected for this question was purely based on girls' responses. The post-test survey included the same items, however, another section consisting of open-ended questions was added to capture students' experiences and perspectives on the stem.T4L Project.

The quantitative data collected through Qualtrics was analysed and the mean scores of pre and post surveys were calculated. Also, a Paired Sample T-test was run to measure the statistical significance of pre and post mean scores. To analyse and generate themes or patterns within the qualitative data, a thematic analysis was conducted. The commentaries provided by students were detailed and insightful and suggested their heartfelt appreciation and excitement for the stem.T4L Project.

### 1.1. RATINGS OF 21ST CENTURY SKILLS

So, how did students rate their self-perceived 21st century skills? Was there any improvement in their capabilities from pre- to post-assessment that could suggest that the project had a positive impact? The answer is yes. As shown below, the initial level of agreement with the items of 21st century skills was between 3.41 and 4.18, meaning 51% to 82% of students generally agreed or strongly agreed with the items in the pre-test. As mentioned above, the higher the agreement, the higher student self-perceived ability was. As the second column of each table shows, the mean scores of all items had improved in the post-test survey, with the agreement level averaging between 3.45 and 4.28. For instance, in pre-test 51% agreed that they could speak in public easily and 63% believed they could communicate their thoughts to others effectively. In post-test, 51% figure increased to 53% and 63% increased to 69%, which could indicate an improvement in these measures of student capabilities.

| Variable 1: Problem-solving | Mean Pre-test | Mean Post-test |
|---|---|---|
| 1. I try to find solutions to the problems I face | 4.04 | 4.15 |
| 2. I am confident in my ability to fix my problems | 3.87 | 3.97 |
| 3. I try to understand why things do not work | 4.01 | 4.10 |
| 4. I transfer new knowledge and new learning into new contexts | 3.83 | 3.96 |

| Variable 2: Communication | Mean Pre-test | Mean Post-test |
|---|---|---|
| 1. I can communicate my thoughts to others effectively | 3.75 | 3.86 |
| 2. I like to talk with others about my ideas. | 3.90 | 4.00 |
| 3. It is easy for me to speak in public | 3.41 | 3.45 |
| 4. I am a good listener and respect peoples' ideas | 4.15 | 4.20 |

| Variable 3: Leadership | Mean Pre-test | Mean Post-test |
|---|---|---|
| 1. I like to be an effective leader in group activities | 3.81 | 3.96 |
| 2. I can inspire people around me by the way I act and think | 3.63 | 3.74 |
| 3. It is easy for me to build strong relationships | 3.74 | 3.89 |
| 4. I demonstrate passion and courage when performing an activity | 3.83 | 3.92 |

| Variable 4: Critical thinking skills | Mean Pre-test | Mean Post-test |
|---|---|---|
| 1. I am a curious person and always have questions | 3.81 | 3.88 |
| 2. I question things before accepting them as truth | 3.89 | 3.94 |
| 3. I analyse my understanding of ideas when I learn something new that may challenge those ideas | 3.75 | 3.86 |

| Variable 5: Creativity and Innovation | Mean Pre-test | Mean Post-test |
|---|---|---|
| 1. I can think of new ways of doing things | 3.98 | 4.08 |
| 2. I am not afraid to fail | 3.78 | 3.94 |
| 3. I am a creative person | 4.13 | 4.25 |
| 4. I like to try out my ideas to see if they work | 4.18 | 4.28 |

| Variable 6: Teamwork and collaboration | Mean Pre-test | Mean Post-test |
|---|---|---|
| 1. I work well in groups | 3.99 | 3.99 |
| 2. I learn a lot from others when I work in groups | 3.92 | 3.98 |
| 3. I would like to work with people who have different ideas than I do | 3.83 | 3.96 |
| 4. Working with others is better than working alone | 3.89 | 3.95 |
| 5. I can contribute valuable information to the group I work with | 3.94 | 4.05 |

Table 1 below compares the mean scores of each skill in pre and post-test surveys. As indicated by the overall mean scores, the highest rating was given to Creativity and Innovation in both pre (M=4.02) and post surveys (M=4.14), suggesting that students perceived themselves to be highly creative and even more so by the end of the project. Another interesting observation was that Leadership had the lowest rating at 3.75 in pre-test. However, the mean increased to 3.88 in the post survey, leading to an increase by 0.13. Moreover, an increase of almost 0.10 was observed for all the skills in post-test that could highlight the positive impact of the project on students' 21st century skills.

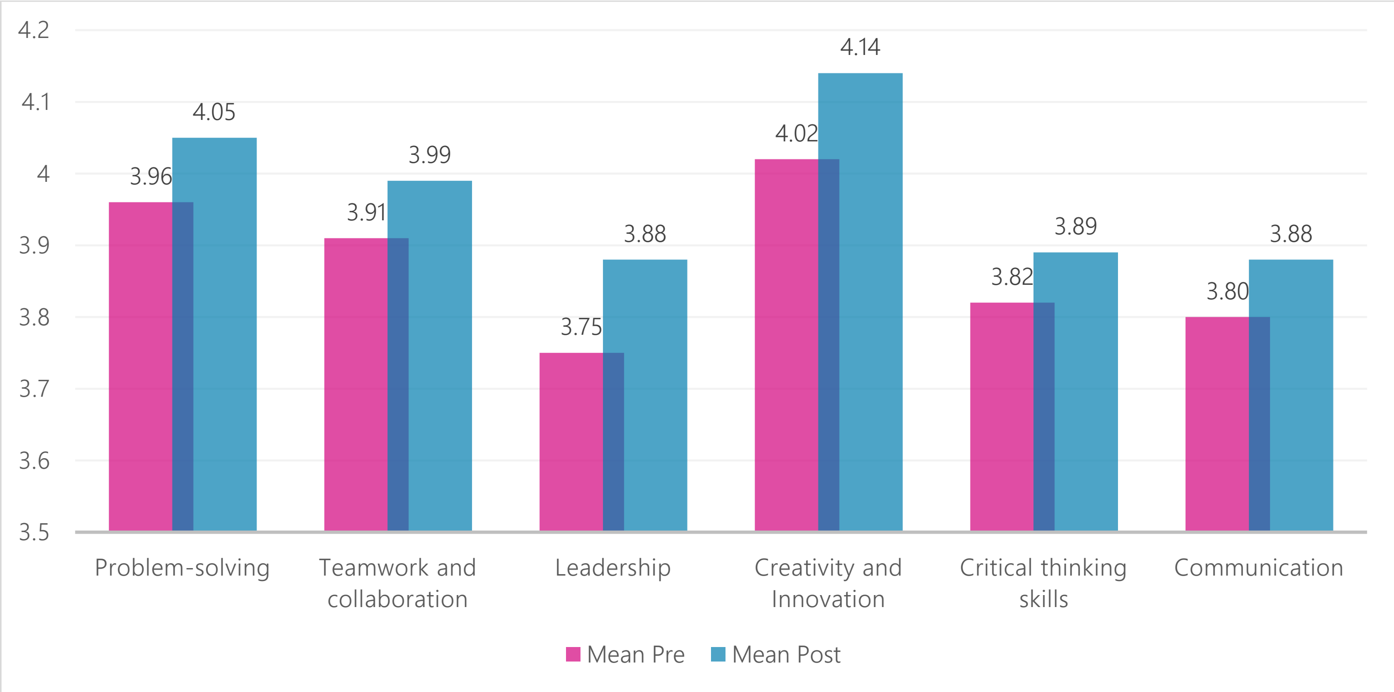



Table 1. Pre and post mean scores of students' 21st century skills

In order to understand if the difference between the mean scores of pre and post surveys was statistically significant (i.e. sig=00<0.05) or only due to chance, a Paired Sample T-test was needed (Table 2). The T-test revealed statistically significant results for students' 21st century skills (sig=00<0.05), meaning the stem.T4L equipment did enhance students' 21st century skills by providing an authentic learning environment where students were thoroughly immersed in creating, collaborating and working in team.

| | Mean | Std. Deviation |
|---|---|---|
| Pre | 91.75 | 8.05 |
| Post | 95.89 | 15.28 |

| Paired Samples T-Test | | | | |
|---|---|---|---|---|
| | Paired Differences Mean | t | df | Sig. (2-tailed) |
| Sum Pre-Sum Post | 4.14 | -6.92 | 798 | .000 |

Table 2. Paired Samples T-Test on total mean scores of pre and post surveys

This favourable outcome mirrors prior educational research which shows that 21st century skills develop significantly when students actively experience new learning situations, particularly those where they can exercise self-reflection, through identifying their strengths and weaknesses, negotiate, make decisions and take on responsibilities (Kolb & Kolb 2005). Looking closer at the learning challenges designed for each stem.T4L kit, we see a strong emphasis placed on development of each of these skills. Through the group and class discussions that occur as students actively engage in and participate in learning activities, they "connect, construct, and contemplate" repeatedly (stem.T4L Learning Library). Ample opportunities are also presented to students to self-assess and give and receive feedback, and these opportunities fully engage them in the learning process and enable them to direct their own learning.

## 1.2. GIRLS' STEM SELF-EFFICACY

One way to attract girls to STEM is to create learning environments that are collaborative and hands-on and encourage creativity and practical applications (Koch, 2002; Wenglinksy, 2000). Therefore, it was assumed that when girls take advantage of STEM technology and have the opportunity to be creative and collaborative, their STEM self-efficacy would increase and they would adopt a more positive attitude to STEM. 5 items were designed to assess girls' STEM self-efficacy and STEM attitude before and after the implementation of the project. To examine girls' attitude to STEM, the survey investigated some of the prevalent stereotypes about boys being better at math and science than girls, and science and engineering careers being better suited for males (Herbert & Stipek, 2005; Jacobs et al., 2002; Simpkins, Davis-Kean, & Eccles, 2006). Items 1, 2, and 5 (below) were negatively worded and were thus reverse coded during data analysis.

In total, 1,050 girls responded to the pre-test and 427 completed the post-test survey. However, analysis was limited to the data from the schools that had completed both pre and post-test surveys (N=381). The mean scores of pre-test items show that the agreement level was between 50% and 65% (M= 3.43 and M=3.97). In other words, at the outset of the project, girls participating in the survey did not demonstrate high STEM self-efficacy, while only around 50% believed STEM careers would interest boys and girls equally (item 5).

| Girls' STEM Self-efficacy | Mean Pre-test | Mean Post-test |
|---|---|---|
| 1. When I face a technical or complex problem I usually ask boys to fix it for me | 3.72 | 3.61 |
| 2. If I was a boy, it would be easier for me to understand mathematics and science because boys have better analytical skills | 3.89 | 3.40 |
| 3. I know I can be as successful as boys in engineering | 3.97 | 4.09 |
| 4. I feel as capable as boys when fixing technical problems | 3.87 | 3.97 |
| 5. I feel STEM (science, technology, engineering, mathematics) fields would particularly interest boys | 3.43 | 3.60 |

Table 3. Pre and post mean scores of Girls' STEM self-efficacy

At the conclusion of the project, there was a slight improvement in the mean scores of some items, however the T-test suggested the difference between the mean scores was not statistically significant (0.59>.05) and the increase in the mean scores of some items was a chance event.

| | Mean | Std. Deviation |
|---|---|---|
| Pre | 14.98 | 3.46932 |
| Post | 14.77 | 3.99050 |

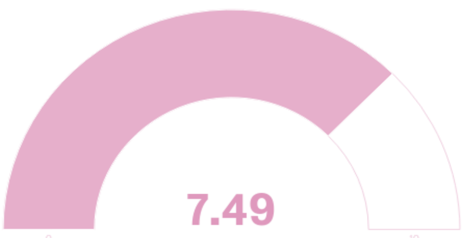
| Paired Samples Test | | | | |
|---|---|---|---|---|
| | Paired Differences Mean | t | df | Sig. (2-tailed) |
| Sum Pre- Sum Post | 0.21 | .538 | 192 | 0.59 |

Table 4. Paired Samples T-Test on total mean scores of pre and post surveys

Although a number of research studies on girls' STEM self-efficacy and attitude report an overall increased interest in STEM and higher level of STEM confidence due to specific program implementation (Dubetz & Wilson, 2013; Goodyer & Soysa, 2017), we did not observe any changes in girls' STEM self-efficacy in this research. One reason for the observed lack of improvement in girls' STEM self-efficacy could be the short duration of the project and limited opportunities to work with the kits. The data suggested that only 32% of girls used the kits on a regular basis (daily/2-3 times a week/more than 3 times a week), whereas 68% pointed out that they had limited exposure to the kits (i.e. once a week: 32%; only once: 28%; and once in a fortnight: 7.57%). increased access to the equipment could have facilitated a greater familiarity with the affordances of the equipment and improved interest in technology. Also, based on the commentaries made by girls, a small number of girls found the kits off-putting as they felt the kits were "built only for boys", which could have allowed for slight disengagement from the kits. However, as will be explained below, most girls, like boys, did enjoy the opportunity to work with stem.T4L equipment.

## 1.3. STUDENTS' RATING OF THE STEM.T4L PROJECT

A reliable estimate of the effectiveness of a project is respondents' voices as they reflect on their experience. To this end, students were prompted to rate stem.T4L Project by giving a score from 0 to 10, where 10 indicated their highest satisfaction. As the gauge chart shows, the average was found to be at 7.49, suggesting that the majority of students were highly satisfied with the project.




Students cited various reasons for their general sense of satisfaction and positive evaluation. Some noted that the kits were enjoyable, interesting and challenging, and represented a new and fun way to learn. Some examples include:

- *Because not only you get a break from literacy and maths you learn a lot more about that.*
- *Fun to use and easy to do.*
- *I have given this rating because it was very enjoyable and fun too and the kits were interesting and I had not done anything like this before.*
- *Because IT helps people understand the meaning of the stem.*

I give a 10 because robots are really fun to work with! It was fun because it combined with many subjects E.g. maths, science, technology, engineering and it includes many more. Robots can be very challenging as well.

- *I have put this rating because it has helped me with coding.*
- *Because I really like to design the 3D printed things and I love engineering and science. Science is really interesting and fun and engineering is amazing and also really interesting. A 10/10 would really suit the way I love STEM.*
- *I gave it a 10 as it showed me virtual reality, which helped in Geography as we are learning about the Great Barrier Reef. This helped me understand and have a deeper understanding when talking about the reef.*
- *It was kind of my first time using robots and my first experience was amazing. The robots were cool to use and obviously code it. That is why I give it a 10.*

It was a brand new way of learning that I've never experienced.

- *I have given this rating because it is a fun way to learn and has given me heaps of knowledge about science and stem.*
- *The virtual reality was very realistic. It made me think that I was actually there. It could*

*improve by letting us see our body in the gear. It could also sense our movement and move the image a little bit to the direction we moved.*

- *It was fairly easy to use but also very educational and fun, anyone can use the kit and the robots to be creative or learn why it is doing the things its doing.*
- *I am giving this rating because I think the robots were not only fun but were also exciting and you learn all about how artificial technology works and how you can communicate with them*
- *I liked how it got me out of maths, that was kinda it, I mean it was sorta boring but we didn't really have to do much soooooo*

Students also pointed out that the kits gave them the chance to do team work, stretched their imagination, and helped them be creative and think outside of the box.

- *Very creative with many possibilities.*

Because I can share my ideas with others and it challenges me.

- *Because the stem kits are a very good way of teaching us kids about the jobs of the future.*

It is really fun because it increases my imagination and leadership and teamwork. It keeps me calm when I am stressed out.

- *I gave the stem.T4L kit a high rating because it had the ability to build anything we wanted and it did not matter what our designs looked like because they were all creative. It also gave people a new creativity none of us has ever been able to express.*
- *With the STEM program it was good they just need to try and get more girls entertained by the STEM program.*
- *Because you could design your own plan without anyone telling you what to do.*
- *Because I can do things that I usually can't do like making a house, rings, and exploring opportunities that are almost impossible for my age.*

Because it made me think outside of the box and use creativity to solve problems. It was exciting and interesting as I got to learn new things.

There were dissenting voices in the data, and some students identified elements that they found frustrating or problematic. Technical difficulties were the main cause of students' dissatisfaction or frustration, including the devices breaking down and "malfunctioning", pieces going missing, and the VR kit not having a strap and its vision being blurry.

Because working with the 3D printer was fun and interesting but sometimes when I was using Tinkercad things didn't do what they were supposed to do and it made me frustrated.

- *Because you cannot move and it doesn't feel realistic at all.*
- *Because sometimes it processes and sometimes it doesn't.*
- *Because the kit is good but has limited supplies and not many instructions.*
- *Bad graphic.*
- *I give the kit a 5 because it is very poor quality, but it was a very fun and new experience.*
- *We had only used it once in term 1, due to the fact that the router was not working and had to be replaced.*
- *We had internet issues with the router connecting the VR set and many issues were made. It took a very long time (like about 10 weeks or so) to make the route connect with the VR head set.*
- *Because I liked it, but sometimes I would get frustrated or bored when things don't go as planned because somebody mucked it up or when we use computers as its slow.*
- *I have given this rating because I particularly am not very interested in robotics/ stem.T4L kits. I am still very grateful we are able to use them at our school they are also quite fun to build and code.*

- *The headset provided an okay experience, but the router kept malfunctioning and was cumbersome to organise.*
- *Because it would break very easily.*
- *Although it was very fun, it was really bad for my eyesight, and it was very illusionary. It didn't teach me much, either, so I don't think it's a very good kit.*

Some pieces were missing and one of our motors kept stopping working then working again. It was quite frustrating to make our coding work.

- *When I used the kit, I felt that I was actually there. It was really cool. The problem was that there were always watermarks on the photos which made it seem less unrealistic. Some photos were also blurry.*
- *Whilst the kit itself was good, the instruction manual was a little harder to understand. It was also a little hard to operate and charge the EV3 Stormbreaker(?) battery pack.*
- *I've given this rating because the VR kit was really fun but it was a little bit annoying that... 1. We had to hold the headset with our hands. 2. We couldn't see where we were actually going and kept on bumping into each other. To improve I think there should be an option where half of the screen is VR and the other half is real life so we can see VR and real life all at once.*
- *The quality of the vision you saw inside the headset was a little blurry, had a slight glitchy, and occasionally hurt your eyes. It may have just been due to the brightness or the fact that some people have sensitive eyes though.*
- *An eight because sometimes I couldn't focus the goggles and it made me a little sick if I used it too much over a period of time. It would've hit a 10 if these things were not a problem for me and I would've loved a video virtual reality as well to see everything moving in the headset.*
- *Because some parts of it are missing. And there's nothing you can really use it for.*
- *Because some of the pieces would get lost easy cause there small.*
- *I gave this rating because I think it was very interesting and I learnt a few things. The only reason why I didn't rate it a 10 is I think the lenses could be a little more clear because it was kind of blurry, and I wish it had a strap so you can put it on without holding it because in my perspective my arms were hurting afterwards because of holding it.*
- *Most of the pieces were missing and some of the pieces did not work but all together it was a great experience and I would love to do it again.*

It is mainly built for boys not girls because people think boy are smarter than girls.

The final activity was to offer suggestions and ideas for improvement. Students generously shared their thoughts, some asked for modifications to the kits, and some put forward ideas for new kits. For instance, a number of students pointed out that the VR headset needed a strap as it was hard for them to hold the headset. A few students mentioned that the kits should suit varied tastes and "inspire different ages and gender", such as appealing to girls or students with artistic interests. Another creative idea that was shared by a few students was to include "manuals", "instructions", and "tutorials" in the kit. A number of students mentioned that they could simply follow the instructions and watch tutorials (if provided), to learn how to work with the kits, which conveyed their interest in taking ownership of their own learning. Further examples included:

- *Just give a strap for the head and more time.*
- *Yes. The 3D printer could go faster and the instructions could explain how to get the 3D printer working.*
- *I believe you should have more examples and instructions of robots. This is because if someone is a beginner and isn't sure how to do something they can reference to the instructions. Also there should be instructions on how to put different sensors into place especially the colour sensor. Also there should be more variety to choose from so its not so box like and also so we have more materials to choose from.*
- *More headsets.*
- *It would be more realistic to find less blurry images without trademarks.*
- *To have a manual about specific details about where to put their things.*
- *The only thing that I would change is that you could print in colour. That would be really good because it would look better than paint and permanent marker.*
- *To put strappers so we don't hold them.*
- *A robotic animal so we can program it to act like that animal.*

Include items that can help students understand what they enjoy and open their eyes to different career possibilities.

- *Try and add a way to keep the VR close to the head without needing hands to hold.*
- *I think that you can put straps to wrap around your head.*
- *I think a really great improvement would be to add a strap around your head and make what you see videos instead of pictures.*
- *I think a way to improve the kit is adding head straps to avoid possible damage.*
- *Put more learning things in there I am not saying that you don't have any but just maybe put more in it.*
- *Give more examples of things each kit can create. Our kit only had a specific kind of robot that we cold slightly modify but we saw cooler and more interesting robots on the manual cover. Provide examples for multiple courses that could be present with each robot type.*

I think all the robots should be solar powered and should absorb enough sunlight in the batteries that it does not need to be in the sun all the time.

- *With the ozobots maybe you could make it so it only follows texter lines because they could see through our paper and were following the carpets lines.*
- *It should have a setting on the camera so you cannot see anything that is human. so we don't have to hide somewhere where it hurts to bend down. Also we would be able to put on the googles and talk to people at other schools. This would be good to meet new people and hear different voices and names.*
- *Possibly kits with animals, and more designs that will inspire everyone from all ages and gender.*
- *To make sure you come fix them when they are not working.*
- *Maybe do activity that everyone would like. For example, students who likes art they can use different chemical solution on dyed cabbage juice paper to find out what colour will be created n just have fun with it.*
- *Have interactive images.*

- *You think that it would be better if there was a tutorial for it so then student who are new to the Kit can see how it all works.*
- *More headsets.*
- *Collaboration with other technology companies.*
- *Yes I do maybe put some straps so student don't have to hold it up to their face.*
- *I think that the VR should be more interactive like moving object or you can explore the whole area then be stuck in one spot moving around.*
- *Computer that followers you.*
- *Check the kits before being passed to another school and replacing bits missing as it can get annoying when building the ev3's.*
- *I think if you are really good at following the instructions for the stem kit at the back there should be a circuit that is half finished and the students have to make the other side and see if it works.*

To get more girls entertained.

- *Communicate more in person*
- *Make sensors and create emotions.*
- *To make it cheaper so that schools or families can afford to buy more and have more fun.*
- *Maybe to make them be able to grab things like little arms to carry light things.*
- *Make sure everything works before you give us the kit and that all the pieces are there.*

Do one for girls especially.

- *You should make it so the person could actually move around (for e.g, walking, jumping).*

## TEACHER SURVEY

426 teachers participated in the pre-test survey administered at the beginning of Term 1, and 350 completed the post-test survey run at the end of the term. Given that in a pre-test/post-test design the research population should be exactly the same, the respondents who had completed only the pre or the post survey were discarded and those with both surveys completed (N=150) were included in the analysis. The majority of teachers that participated in the research were primary teachers (84%) and female (78%). 39% of teachers rated their knowledge of technology as "above average", while the majority had an "average" knowledge of technology (47.42%) and the rest were below average (13%), which could have a bearing on teachers' ratings of their STEM self-efficacy. In fact, research in technology education shows that teachers' attitudes and perceptions of technology is a predictor of the extent to which they adopt technologies in their classrooms. In other words, if teachers are not confident in using technology themselves, they are unlikely to adopt them in their classrooms (Capo & Orellana, 2011; Miranda & Russell, 2012), and this could impact STEM education more broadly.

### 1.4. TEACHERS' STEM SELF-EFFICACY

Given that 60% of teachers participating in this research indicated an average or below average competence in using technology, it was worthwhile to explore their competence and confidence in STEM teaching to further investigate the impact of stem.T4L Project on development of their STEM efficacy. At the outset of Term 1, the mean score of teachers' STEM self-efficacy was at 3.68, meaning around 40% of teachers were not ready for STEM education.

However, as the table below shows, *all* the mean scores of STEM self-efficacy items increased in the post test and the total average improved to 4.00,

which suggested 79% of teachers felt confident to teach STEM by the end of the term. For instance, only 53% of teachers believed they knew how to expand their repertoire of knowledge and skills regarding STEM teaching (item 6) at the beginning of Term 1. By the end of the term, 80% of teachers were confident that they knew where to go to learn more about STEM teaching. Also, the lowest rating amongst the efficacy items was given to item 7 in the pre-test, where only 44% believed they had enough knowledge to teach STEM. In the post-survey, this proportion increased to 63%, suggesting a major boost in teachers' confidence in their knowledge to teach STEM.

To examine the statistical significance of the pre and post mean scores, T-test was used. It was found that the increase in the mean scores of post-test was statistically significant (sig=00<0.05), suggesting an actual improvement in teachers' STEM self-efficacy from pre to post-test.

| | Mean | N | Std. Deviation |
|---|---|---|---|
| Pre | 29.67 | 150 | 5.57 |
| Post | 32.08 | 150 | 4.60 |

| Paired Samples Test | | | | |
|---|---|---|---|---|
| | Paired Differences | t | df | Sig. (2-tailed) |
| | Mean | | | |
| Sum Pre - Sum post | 2.40 | 4.139 | 149 | .000 |

Table 5. Paired Samples T-Test on total mean scores of pre and post surveys

| STEM Self-efficacy beliefs | Pre-test Mean | Post-test Mean | Frequent users of kits Mean |
|---|---|---|---|
| 1. I have confidence in my ability to teach STEM | 3.62 | 4.00 | 4.15 |
| 2. I can engage students in STEM activities | 3.92 | 4.26 | 4.33 |
| 3. I am able to answer students' questions related to STEM | 3.60 | 3.94 | 4.04 |
| 4. I can help my students value STEM learning | 4.10 | 4.25 | 4.37 |
| 5. I can help students who are confused about STEM subjects | 3.69 | 3.96 | 4.04 |
| 6. I know where to go to learn more about STEM teaching for myself. | 3.48 | 4.01 | 4.17 |
| 7. I have enough knowledge to teach STEM | 3.24 | 3.66 | 3.77 |
| 8. I am confident integrating technology into my lessons | 3.79 | 3.98 | 4.13 |

Table 6. Pre and post mean scores of teachers' STEM self-efficacy beliefs

Another interesting finding further reflected the noticeable impact of the stem.T4L project on teachers' STEM self-efficacy beliefs. The study compared teachers who used their stem.T4L kit more than 3 times a week (45%) and those who used it only a few times in total (55%). As the last column of the table above shows, there was a substantial increase in STEM self-efficacy for the former group from pre- to post-test across each of the 8 items. For instance, at baseline, 71% of teachers declared that they were confident integrating technology into their lessons (item 8). While this figure improved to 85% for frequent users of the kits, for the rest of teachers the rating increased only up to 80%. In other words, the more extensive their experience of the kits was, the more confident teachers grew in integrating the stem.T4L equipment in their daily classroom routine. This finding is supported by research that shows feelings of confidence are facilitated by having teachers use technology (Ertmer & Ottenbreit-Leftwich, 2010). Hence, it is highly likely that teachers will experience a major boost in their competence and confidence in STEM technology as they continue to use stem.T4L Community kits for a longer period of time.

Based on these findings, it can be concluded that engagement of teachers in the stem.T4L project enhanced teachers' STEM self-efficacy.

A similar outcome was achieved from Term 4 research (2018) and it indicated growth in teachers' STEM self-efficacy from before to after implementation. Table 7 below shows the comparison between the mean scores of pre and post-tests in Term 4, 2018 and Term 1. As previously discussed, teacher efficacy is positively associated with student achievement, and teachers with high levels of self-efficacy are more persistent, resilient, and better equipped to address student learning (Cantrell, Young, & Moore, 2003; Protheroe, 2008; Tschannen-Moran & Hoy, 2001). By improving teachers' STEM self-efficacy, we can expect an increase in the number of students who are interested in STEM and more likely to pursue STEM fields.

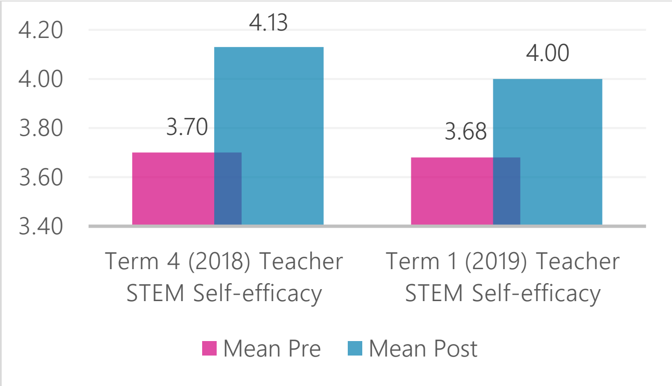



Table 7. Difference in teachers' STEM self-efficacy in two terms

Now the question was: from the perspective of teachers, what factors contributed to an increase in their STEM self-efficacy? In other words, what factors assisted teachers to successfully apply STEM technology in their classrooms? The comments provided by teachers showed that there were a myriad of factors involved, most of which could be categorised under stem.T4L Community Professional Learning (PL). Other factors included school climate, self, and student participation (Table 8).

| stem.T4L Community Professional Learning | School climate | Self | Student participation |
|---|---|---|---|
| 1. Video tutorials<br>2. The Learning Library<br>3. stem.T4L Leaders<br>4. Face-to-face PL<br>5. YouTube videos<br>6. Learning challenges<br>7. Online webinars | 1. Supportive staff in school<br>2. Time of year<br>3. Supportive school leadership team<br>4. Collaboration with staff | 1. Prior knowledge/experience<br>2. Taking the kit home and exploring<br>3. Confidence<br>4. A passion/ eagerness for integrating technology into learning | 1. Knowledge of students in using STEM<br>2. Highly engaged students<br>3. Enthusiastic students |

Table 8. Factors contributing to teacher readiness to implement STEM technology

For the majority of teachers, different components of stem.T4L Professional Learning, such as the learning library, face-to-face workshops, and online workshops expanded their knowledge of STEM technology and boosted their confidence in integrating stem.T4L equipment. This finding provides further support for the key role of Statewide Professional Learning in preparing teachers for STEM education by improving teachers' STEM engagement, awareness, and competence (Sondergeld, Johnson, & Walten, 2016). Some examples include:

Learning Library and videos showing set-up and use of devices.

- *We had a demonstration by an expert in the field. YouTube how-tos were excellent.*
- *Everything is in the kit, ready to use. I also loved the You-tube videos which helped me work out how to best use the equipment.*
- *Using the videos and video conferences.*
- *Online webinar.*
- *Professional learning session.*

STEM Share library video tutorials. Discussion amongst teachers within the school.

- *By having a stem.T4L expert attend school regularly for face to face.*
- *PL on how to use the stem.T4L equipment.*
- *PL by a staff member, Reading of relevant information prior to lessons, opportunity to play with the ozobots prior to lessons.*
- *The stem share library resources.*

Face to face training and time to experiment with the kit before having it at the school as an educational tool.

- *Online videos, other examples are you tube, face to face training.*
- *The How to videos helped me to understand what all the equipment was and how to utilise it. The activity suggestions were also good to follow and students enjoyed them.*
- *Face to face training. Students' willingness to share their ideas and shortcuts in TinkerCad. Throughout the term there has been a lot of STEM share training including workshops and at Wagga at the EDconnect, which will also help in the future.*

The stem.T4L library and all its lesson plans and resources.

The teaching resource library and how to videos. stem.T4L team answering calls also assisted greatly.

- *The learning videos were fantastic for helping to set up.*
- *The stem.T4L website contributed greatly as I was able to view videos and programs prior to receiving the kit.*

The stem.T4L Professional Learning I attended last year and looking up the how to videos in the STEM share library.

- *The resources and collaboration with teachers who have more knowledge than me.*
- *The how to videos.*
- *The how to videos and the opportunity to use different resources definitely helped me to implement stem activities in my classroom.*
- *The how-to videos were a great help as I have not previously used a VR kit.*
- *Professional Learning online library and you tube video clips from the net.*
- *The information provided in the STEM share library. The challenges were very explicit and allowed less confident teachers to feel confident introducing new concepts.*
- *A face-to-face professional learning session and access to lesson ideas online.*
- *The face to face course where we were able to play with the equipment and ask questions. but at the time, I didn't know what questions to ask...*
- *Until I attended the course in Wagga I was really blind to what I should be doing before hand so didn't prepare as much as I should have.*

PL from stem.T4L leader.

- *The videos on the stem.T4L library, and units of work that were linked on these pages also.*

- *The face-to-face workshop which gave me the opportunity to experience the kits first hand before implementing in the classroom.*
- *Videos & stemleader face to face contact*
- *Watching the videos. However, I feel they could have included more detail on the use of the Touchcast Studio app.*

Online adobe connect sessions and assistance from the stem.T4L leaders.

- *I used the stem.T4L library units, videos and information to assist me in preparing to implement the equipment effectively.*
- *Had it over the Summer break. 6 weeks of immersion. B. Discussions in community group on Yammer stem.T4L. C. stem.T4L Library. D. Co- Spaces online Tutorials / Youtube.*
- *Reading and watching the videos.*
- *Direction and assistance from stem.T4L leaders, PD at our school (rather than over VC). Student interest and engagement with 'new' technology also played a part in the use and implementation of this kit.*

Face-to-face learning, knowledge was gained and we felt as a whole school that we were ready to implement the equipment successfully.

- *The face to face training provided by our STEM share consultant, ....She was terrific in answering questions and guiding us on the basics.*
- *The Learning Library resources and software applications.*
- *The learning library, face to face learning and online instructions helped me.*
- *I have come from a school where we had LEGO WEDO 2.0 kits so i was a confident user and had also used the dot dash robots before too.*
- *Face to face support was excellent and really helped.*
- *Having support of the stem.T4L leaders.*

The lesson plans to go with the products.

- *The online videos on setting up the 3D printer were excellent and clear.*
- *The face-to-face course I attended increased my knowledge of stem.T4L equipment.*
- *The stem.T4L library was without a doubt made the greatest contribution.*

How to videos in the stem share library.

For some teachers, the collaboration made between staff and the support received from the leadership team in their school facilitated the implementation of the stem.T4L equipment (School climate):

- *Talking to other' at my school and sharing experiences.*

Supportive school leadership team, collaboration with staff on items for implementation, discussion for embedding kits into current teaching programs.

- *Support was given at school by releasing a tech expert every week using school funds to teach STEM lessons in every class across the school, also providing professional learning for staff. I could not have used the equipment without this level of support.*
- *How to resources and supportive staff in school.*
- *Conferences, online resources and lesson examples, support from teachers within my school.*

We had a staff member as "expert" who help professional learning. We discussed at Stage meetings and got students to be mentors.

- *Staff face to face training of each other sharing resources of what works with each other.*

Online activities, someone in our school facilitating it.

For other teachers, seeing students engaged and enthusiastic was encouraging and motivated them to invest time and effort into upskilling (Student participation):

High student engagement, engaging activities, experimenting with new technologies.

- *Enthusiasm of my class and availability of activities to complete with kit.*
- *Just the students' engagement in VR goggles.*
- *Student engagement. A teacher with more knowledge was teaching me and the students the lessons.*
- *The students' enthusiasm toward the robots and their willingness to share their learning with other students within the school.*

A number of teachers also reported more individualised or self-oriented experiences, relating to prior experience, existing self-efficacy and enthusiasm for STEM technologies. These contributing factors were often supported by teachers' use of the PL and Learning Library opportunities:

- *How-to videos and prior knowledge I already had.*
- *The online videos showed me what to do and how to do it.*
- *Passion to implement stem.*
- *My own previous experience in working with STEM technology and other technologies. I was able to spend time experimenting with the equipment which helped greatly.*

A passion for integrating technology into learning. An interest in new technologies how they can help students meet syllabus requirements in all KLA's.

- *Prior knowledge Learning Library Face to Face PL.*
- *Students' engagement and interest.*
- *Online library resources, time to use the equipment and test it myself.*

Know how to integrate the technology to the science units taught.

- *Prior knowledge of the equipment and efficient ways to use it. Due to our school having the 3D printer for two consecutive terms.*
- *My prior knowledge of WeDo 2.0 and Dash & Dot.*
- *My personal knowledge and experience with the equipment gave me confidence to use it in the classroom.*
- *My own eagerness to incorporate it into my lessons, I had to encourage some colleagues to give it a go.*
- *Just being keen to try something new.*

Learning library resources. My own interest. Training.

## 1.5. TEACHERS' EXPERIENCE OF STEM.T4L PROFESSIONAL LEARNING

Teachers proactively highlighted the contribution of stem.T4L Professional Learning (PL) to their sense of STEM competence and confidence in the above section. In the survey, we also measured the effectiveness of the PL to identify its strengths and weaknesses from the perspective of teachers. Since the launch of the project, approximately 15,000 teachers have participated in the stem.T4L Community Professional Learning. The data collected through Feedback Forms administered at the end of each event, and the research surveys showed that teacher' satisfaction level has been at and above 85%, as depicted below.

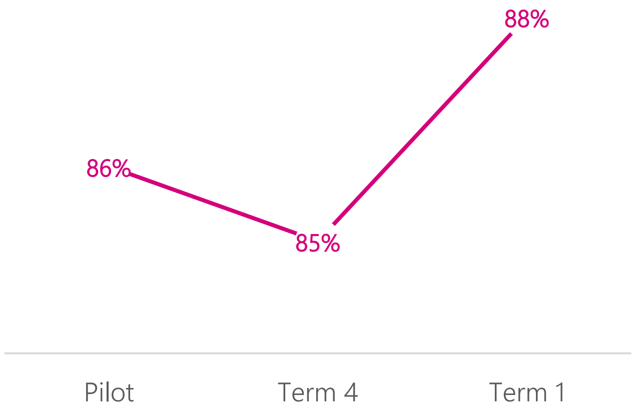



Table 9. Teachers' satisfaction of PL

In Term 1, 79.81% of teachers who completed the post-test survey indicated that they participated in PL opportunities, either through accessing the Learning Library and how-to-videos, receiving one-on-one coaching, or participating in conference events. The ratings also suggested that the majority of teachers drew upon how-to videos (36.30%), and the Learning Library (29.79%) to upskill, as Table 10 below shows (please note this question was a multiple answer and teachers could check off all the choices that applied to them). Out of 292 answers recorded for this question, only 52 (17.81%) involved face-to-face coaching, which might carry implications about ease of access and availability of face-to-face training. However, it is worth noting that in Term 1 approximately 5,000 teachers participated in PL events. The data presented in Table 10 is based on the responses provided by 150 teachers that completed the survey.

| PL Opportunities | Count | Percent |
|---|---|---|
| Face to-face Training | 52 | 17.81% |
| Virtual conference events | 47 | 16.10% |
| Learning library resources | 87 | 29.79% |
| How-to videos | 106 | 36.30% |
| Total | 292 | 100% |

Table 10. Teacher participation in PL

Table 11 compares the mean scores of PL items across the 3 terms. We observed that over 88% of teachers had high satisfaction and appreciation with the resources and learning materials put at their disposal (item 1 across the 3 terms), leading to construction of new knowledge and enhancement of teachers' STEM teaching skills. However, whereas the mean scores of almost all items improved from Pilot to Term 4, only 3 items (i.e. items 5, 6 & 8) experienced an increase in their mean scores from Term 4 to Term 1. One item which had a particularly gradual rise was item 8 ("I collaborated with other teachers outside of my school on stem.T4L Project"), where teacher collaboration improved from 2.84 (34%) in Pilot to 3.11 (40%) in Term 1.

| Professional Learning | Mean Pilot | Mean Term 4 | Mean Term 1 |
|---|---|---|---|
| 1. I am satisfied with the resources and learning materials provided by the stem.T4L project | 4.14 | 4.43 | 4.26 |
| 2. Engagement of my students increased because of my new knowledge | 4.05 | 4.25 | 4.21 |
| 3. I collaborated with other teachers at my school on stem.T4L | 4.07 | 4.20 | 3.85 |
| 4. The learning library increased my knowledge and expertise of STEM teaching and learning | - | 4.08 | 4.16 |
| 5. I improved my teaching of STEM because of the professional learning | 3.73 | 3.93 | 3.98 |
| 6.The professional learning further developed my understanding of STEM concepts | 3.80 | 3.91 | 3.99 |
| 7. The stem.T4L leaders helped me to implement quality learning activities | 4.00 | 3.82 | 3.79 |
| 8. I collaborated with other teachers outside of my school on stem.T4L | 2.84 | 2.91 | 3.11 |

Table 11. Pre and-post mean scores of PL across 3 terms

The commentaries made by teachers also confirmed that the project facilitated collaboration between teachers. Teachers pointed out that they initiated talks and discussions either through social media or face-to-face collaboration during the course of the project. Sharing the kits provided the opportunity to exchange ideas and experiences with one another, which sometimes even led to providing each other with technical support. "Team teaching", "classroom visits", "watching videos submitted by neighbour schools", "hourly interaction in Yammer", "reading the Facebook groups comments", and "asking the previous school for ideas" were some of the examples teachers put forward to indicate their active and effective collaboration with other teachers outside of their school, as suggested below:

- *Teachers in search of ideas got in contact with teachers who had used the kits before and got new ideas and advice to implement in their own classroom.*
- *I know teachers who had had the same kit as my school so I arrange to talk to them about how they used it and gave each other ideas.*

During our next SDD we are attending another school. This school received the same kit we had (PC robotics kit). During the SDD I will be presenting a 1 hour hands on lesson about how to use the kit effectively, how to use the robotics, and how to integrate it into lessons across the KLAs.

- *By sharing what I used it for on social media, that further enhanced the learning and ideas for other teachers.*
- *I was able to work with a teacher from the school who will get the kit after us. We will continue our collaboration after this time.*
- *A teacher from a neighbouring school attended the UTS STEM Project which used stem.T4L resources.*

Through Yammer especially I was able to chat with other teacher about what they had done in their classrooms. I then was able to apply this information to my school context.

- *Teachers needed to work together to work out how to integrate these new technology into the classroom.*
- *The use of the STEM kits was exciting for both the students, and the teachers. I was very happy to discuss what we were doing with other teachers outside of our school*

*about the advantages of the kits, and what we had all learned.*

- *Good discussion, sharing ideas, exchange of experiences and talked about other options for technology implementation*
- *Conversations about how and why we taught certain lessons. Brainstorming ideas that other schools have used. I also rang other schools for maintenance assistance.*
- *Combined schools PL.*

By working with teachers from other schools in sharing knowledge and skills of stem.T4L.

- *Got to speak to other teachers at a conference and they explained how easy the stem.T4L kits were to use.*
- *It allowed us to bring in outside experts to help us understand how to better introduce the students to STEM.*

Asking the previous school for ideas. Reading the Facebook groups comments on projects. Other schools coming into the school and asking about the kits and how they can get them in their school.

- *Being able to share excitement and ideas about what we have tried at our school. Letting other schools know how they can access these resources.*

The Facebook community allowed for instant collaboration. It felt like a supportive community.

- *Every year our school participates with Professional learning with teachers at other schools. I was able to use the kit to run one of these PL sessions for teachers from schools in our community.*
- *I recently attended a robotics day at another school and it was great to hear what kits other schools were using and what they had done.*
- *The Yammer group was helpful and the fact that we have to pass the kits around automatically tells you who knows how to do it already if you need to talk to someone.*

I hosted a Teacher Librarian network meeting while the stem.T4L (VR) kit was at my school, and was able to show the regional TL group the devices first hand. This provided a great opportunity for discussion about STEM learning in the library and ways we can integrate new technologies into our schools and our own lessons.

- *Social forums such as the Facebook group helped educators ask questions and share knowledge. Face-to-face professional development opportunities were fantastic.*
- *During face to face training my colleague and I were able to share the ways we used the stem.T4L kits that we had loaned last year. This guided other schools.*
- *I was able to seek advice and help if needed from others who have used the kit previous to me and offered assistance for those who needed it.*

1. Picking Kit up in person from incoming school. Networking connection made that would otherwise be lost. 2. Drop off of Kit to next school - invited teacher to my school; leading to additional Networking connections made. Face to face beats emailing and phone calls.

- *Collaboration with SSP and Support Unit for integrating technology into lessons for students with additional needs.*
- *More team teaching.*
- *Interaction through the stem.T4L Yammer on a daily, no hourly basis. The shared experience of so many teachers provided great insight.*
- *Greater access to online sites to discuss ideas, professional learning via adobe conferences, ask a question and loads of teacher would answer you, great!*
- *Culminated in the Lego League tournament held at our school.*

By looking at videos submitted from surrounding schools, learning about what STEM learning looks like in their schools, but mainly by communication on Yammer and 'beside' the STEM training on Adobe connect.

- *I taught the next school how to use the kit*
- *In providing the email of the teacher who had the kit before me, I was able to ask what they did. Her idea actually formed the basis of what we did!*
- *Online collaboration via PLN's*
- *Told other teachers about the kits and the way we utilised the robots in class.*
- *Sharing of ideas and projects brought together people who had a common goal*

Teachers from other schools visited my classroom to see the stem.T4L kits could be implemented into lessons to address the Digital Technology Outcomes in the S & T Syllabus.

- *Others saw what we were doing and wanted to do something that was engaging*

The total mean scores of stem.T4L Professional Learning across the 3 terms are presented below in order to compare the overall improvement of stem.T4L Community Professional Learning. As Table 12 shows, the mean score increased from pilot to Term 4 (2018) but it remained almost the same in Term 1 (2019), suggesting an improvement in PL from pilot to Term 4. However, stem.T4L Professional Learning has maintained almost the same performance and momentum towards a successful integration of stem.T4L equipment since Term 4 (2018).

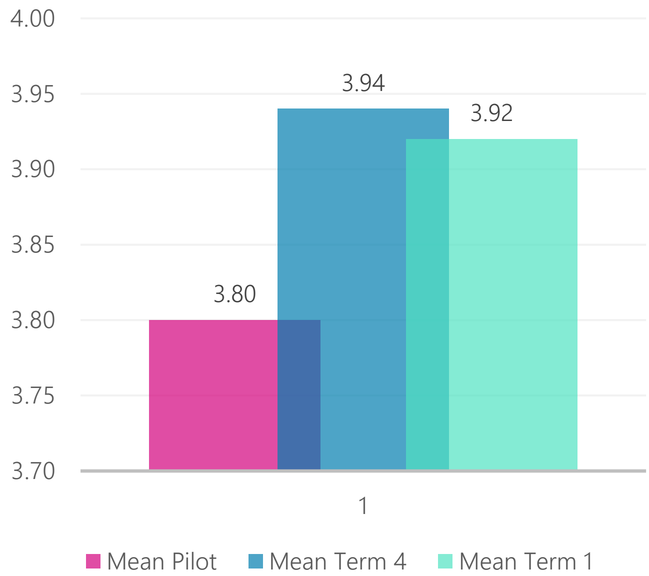



Table 12. Total mean scores of PL in 3 terms

As mentioned above, 20% of teachers did not undertake any stem.T4L Community PL. These teachers were prompted to indicate their reasons for their lack of participation and as Table 13 suggests, not being aware of the availability of these programs and being time poor were the two main reasons. Some examples from their commentaries are provided below.

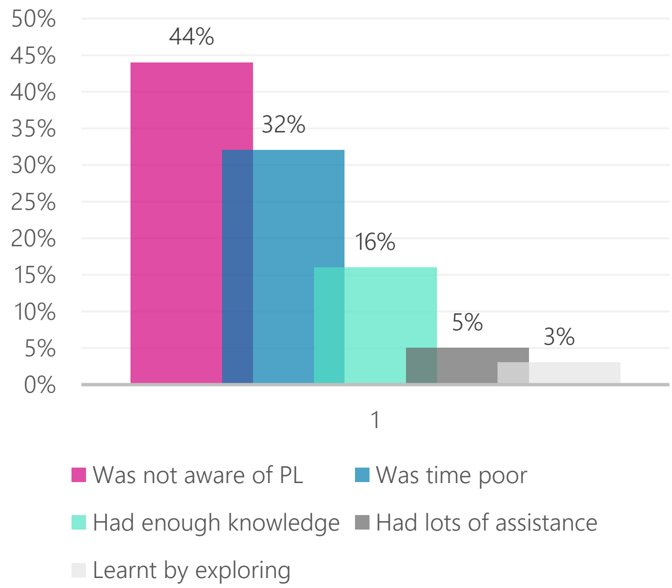



Table 13. Teachers' reasons for lack of participation in PL

- *Didn't have time. Used Google expeditions though!*

- *I was part of the UTS STEM Project so I had lots of assistance.*
- *Did not know about them.*
- *I did not have them.*

To be honest, I forgot what was available and did my own internet searching.

- *Not aware of them.*
- *We had the film kit so already had ideas for implementation.*
- *Our school has an IT coordinator who helped me with my lessons.*

I used other tools to teach myself how to use the equipment and create lessons from that.

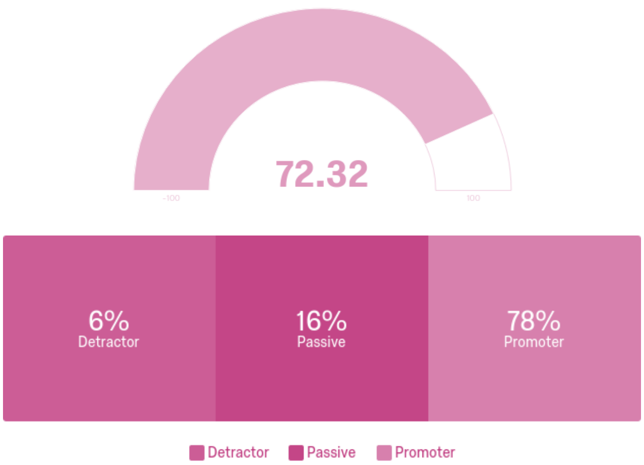
- *Just ran out of time.*
- *I have not really had time at this stage to sit and engage in online learning.*
- *I didn't realise that they were available and don't know where to access them.*
- *Teachers at my school trained me.*
- *I was happy to explore the apps and robots with my students, and felt I had enough knowledge to do this.*

Small school with multiple duties across day plus other priorities during my RFF so did not have enough time.

- *Wasn't aware that there were programs or courses available.*
- *I played with the programs and worked it out.*

## 1.6. TEACHERS' RATING OF STEM.T4L PROJECT

A final assessment of the effectiveness of the stem.T4L Project was performed by measuring teachers' overall ratings of the project. As explained in the Term 4 report, a Net Promoter Score, which ranges between -100 and +100, can indicate respondents' likelihood of recommending a particular program to other people. Traditionally, a score above 0 is considered "good", +50 is "excellent", and above 70 is "outstanding". As shown below, Term 1 teachers participating in this research recorded an outstanding NPS of 72.32, with 78% of teachers being the promoters of the project. Most of the commentaries provided were favourable and teachers cited different reasons for their enthusiasm, positive outlook, and support for the project. Teachers noted "easy to access resources", "heightened student engagement", "effective communication" , "quantity of equipment", "super-portable and very easy to set up equipment", "responsive and supportive leaders", and "excellent PD".




Some teachers focused on student engagement when rating the project overall. A few teachers also reported that this engagement and enthusiasm was conveyed to them by students' parents, which suggests that students are sharing their experiences outside of the classroom.

- *Kids thoroughly engaged.*

It's such an easy way to teach students. The kits make my job so much easier. We would never be able to have access to such a huge range of equipment.

- *My students benefited immensely. They discussed it all at home. I had parents* *approach me so their child could show them what they had learned. The children worked collaboratively on their projects and were happy and engaged the entire time.*

- *It was very engaging for the students.*

- *This rating is partly based on my enjoyment of using the stem.T4L VR kit and the possibilities I see for this type of technology, but also largely influenced by the great excitement and enjoyment my students expressed while using the kit and afterwards. I also spoke with a lot of the parents of my students and they reported hearing great things about the lessons and having been urged by their child to go and buy VR resources for use at home.*
- *Student engagement and process of thought by the students were fantastic.*

The quantity of equipment allowed all students to have access and engage with activities in small groups.

- *Valuable resource to improve student engagement and develop their computational thinking as well.*
- *Students were engaged.*
- *The students were really engaged in their learning and showed great collaboration.*
- *Exposes students to a highly engaging learning environment, which can have a huge impact on student learning, while preparing them for the future.*

The kit interested and excited my students, they were completely engaged in every activity we did involving the robots. I loved how versatile the Dash and Dot robots are, it makes it very easy to integrate them into other KLAs.

- *The enjoyment, engagement and involvement of students was of the highest level. On one particular day the home bell rang, and a collective sigh went out among the students because they did not want to go home! How awesome is that!*

Student engagement is huge. The skills students are acquiring are excellent. I love the collaboration and teamwork, creativity and perseverance I'm seeing.

Others noted the overall ease of use as a reason for giving the project a high rating:

- *They were easy to use, did not require teacher to have all the knowledge. Students easily figured out what to do and did it better than with teacher instructions.*
- *They were easy to access, use and were highly engaging.*
- *It was ready to go and gives a good overview of what robotics are available.*
- *The kit was great with all videos to assist in teaching.*

It was so easy to access the kit and to use it. Programming for this unit was easy as I had access to the stem.T4L library which focused on uses for these robotics in the world and student communities.

- *It was super portable, very easy to set up. Great way to introduce students and teachers to the possibilities of the kit.*
- *All equipment worked easy to organise.*

They are well packaged, well managed and delivered to your school - what is not to love? I have witnessed the growth of confidence of all students who used the kit in a matter of weeks. Once they have the skills need to use the kit and its accompanying apps and web based programs, they can continue to use these skills in other areas and in different topics.

- *Kits are easy to use and stem.T4L leaders are responsive and supportive.*

Again, the resources available to teachers were widely cited as a reason for rating the project favourably. This was often framed in broader terms, such as enabling schools' access to new technologies:

- *Very good information online regarding unpacking etc.*
- *Free, great tips on STEM Share, great sampler, sample units.*
- *This is a fantastic project! Not many schools have the resources or the means to buy enough robots/VR/bluebots to successfully and meaningfully incorporate these into teaching and learning programs.*

It gives a taster. Low stakes. Quick learning. The sense of urgency to use means staff just get in and do it. Little wastage and you can use it to try before you buy and see where it is relevant.

- *Very well organised, and a great opportunity to trial equipment for free.*
- *How else would you have the opportunity to use this equipment that has everything you need plus the "how to" use it guides?*
- *The chance to use technology not readily available in our school environment.*
- *Resources provided including library.*

Materials ready to be used, excellent PD, staff were always willing to help, the kit made it easy to implement important and engaging  programs that may otherwise be missed.

- *Well set up and well supported.*
- *Everything is provided. Ipads with apps already downloaded, all the cords, enough charging stations and a fantastic learning library online for us to access to develop our own skills.*

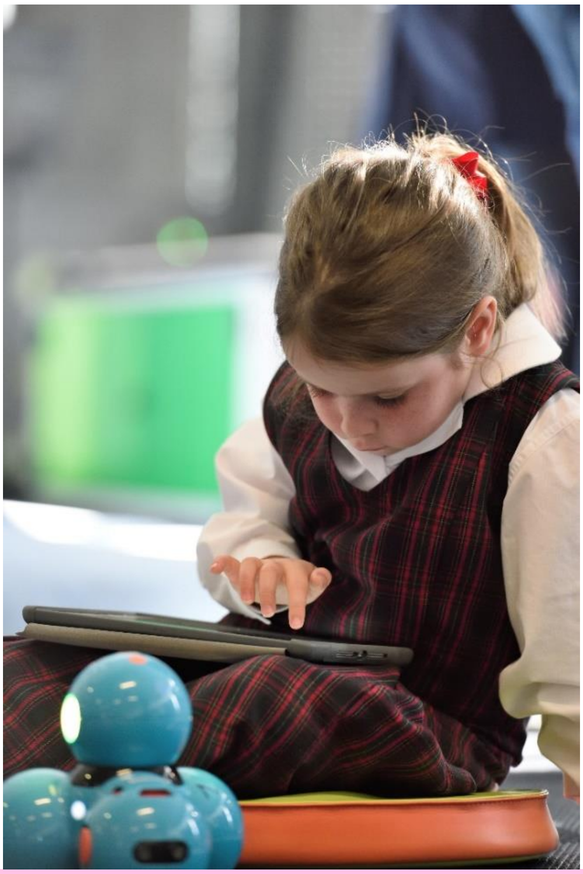
They are amazing and if you need help you can search for the answer in the library or just ask!

- *It allowed our school to have the opportunity to participate in STEM learning experiences that we would otherwise not been able to do so due to budgets, accessibility and locations.*

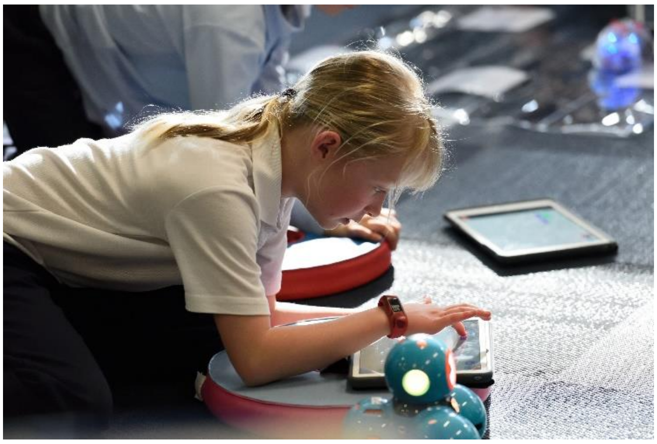
There were also a small number of teachers who were slightly critical of the project as they faced challenges such as "kits not functioning and being unsuitable for some stages", and "lack of collaboration and consultation with staff". While providing this feedback, teachers also made suggestions for addressing some of these constraints. Some examples included:

- *It took a while to get used to, and then most of the term was over. We used the VR kit and had lots of kids feeling sick - one fainted, so maybe not ideal for stage 3.*
- *Kits did not function as required.*
- *They keep dropping out. Not sure if its the iphones or the internet connection.*

Some slight technical difficulties can cause delays in what you are creating eg we had the 3D printing kit and sometimes the prints would fail without know cause. Allow time to complete/print tasks. Utilise the time wisely.



- *Because there was no consultation or collaboration with staff, it turned out to be a stand-alone 'play session' that didn't have any real impact beyond the one hour of access we had per week.*
- *Because you really need tech support and perhaps older children as buddies to trouble shoot during their use.*



- *The Primary VR kit was flawed because it was using iPhones which is incompatible with the content creation side of google expeditions, therefore the whole experience is not complete…*
- *Our kit was broken for the entirety of it's time at our school. Bilby 3D's customer service was poor and I had to replace an extruder all by myself, which I didn't mind, but most other teachers would not have been able to do it. A lot of time was wasted trying to get this printer working. Students did not get to use this either.*

I love the kits. I love that my kids love the kits. I love that, with a little thought, the kits can seamlessly be integrated into my programming. I do despair, however, that many teachers seem too scared or lack the confidence to even try and use the kits in their classrooms. It means that some kids are still missing out even though these kits have reached their school.

The findings of Term 1 research on 799 students and 150 teachers revealed statistically significant improvements in students' 21$^{st}$ century skills and teachers' STEM self-efficacy beliefs. The main findings of this research are summarised below:

1 The mean scores of all the measured capabilities (problem-solving, communication, critical thinking skills, team work and collaboration, and creativity and innovation) increased from pre to post evaluation. An interesting observation was the development of students' self-perceived leadership skills, which had the lowest rating in pre-test but experienced the highest increase in post-test. One reason for the observed differences in the mean scores of all capabilities from pre- to post-test surveys could be the highly interactive environment that the stem.T4L Project cultivated. As confirmed by the majority of teachers, student engagement was remarkable during the course of the project and contributed to lively interaction and collaboration between students. Research also shows that an interactive environment, characterised by student driven rather than teacher led approaches to learning, promotes higher order thinking skills, team work, communication skills and leadership (Mathers, Pakakis & Christie, 2011). Therefore, the findings of this research provide support for the conclusion that implementation of STEM technologies can enhance students' 21st century skills by fostering an environment of collaboration, creativity, higher-order thinking, and teamwork.

2 Despite the positive impact of the project on 21$^{st}$ century skills, no improvement was recorded for girls' STEM self-efficacy, neither did their attitude towards STEM change. More specifically, the pre-test survey revealed that girls had a moderately low STEM-self efficacy prior to the project (M= 3.78), with half of the girls believing STEM fields would suit boys better. The post-test results did not yield a statistically significant improvement and the mean scores remained the same for STEM self-efficacy and attitude.

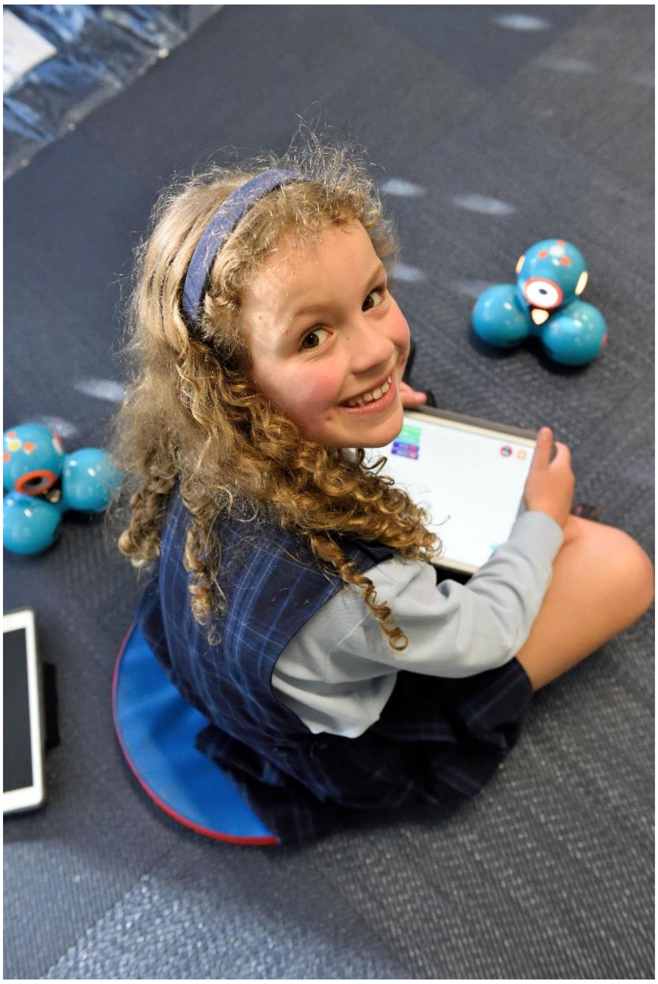
3 The results of the teacher surveys demonstrated that exploring with and using the stem.T4L equipment and activities contributed to an increased confidence and knowledge of implementing STEM technology. At the outset of Term 1, 47% of teachers rated their knowledge of technology as average. Teachers' STEM self-efficacy was also found to be at 3.68, meaning 40% of teachers were not confident to teach STEM. This finding could suggest a close link between teachers' limited knowledge of technology and their low confidence in teaching STEM. There was further evidence of this knowledge-confidence link, as an improvement in teachers' confidence in teaching STEM was observed after they had spent the term using stem.T4L equipment and increasing their knowledge of technology. An average score of

4.00 indicated that 79% of teachers felt confident to teach STEM at the conclusion of the project. Interestingly, there was an even higher increase in teacher STEM self-efficacy for teachers who had used the stem.T4L Community equipment on a regular basis (i.e. more than 3 times a week).

4 79% of teachers who participated in the research undertook one or more of stem.T4L Professional Learning (PL) programs, 88% of which had high satisfaction with their PL experience. A similar level of satisfaction was observed in the research conducted during the pilot and in Term 4 (2018), suggesting that stem.T4L Project continued to deliver high-quality, coherent and meaningful PL.

5 Teacher collaboration improved from 2.84 (34%) in the Pilot to 3.11 (40%) in Term 1. Social media and sharing the kits appeared to facilitate an exchange of ideas and practices amongst teachers.

6 20% of teachers participating in the research did not make use of any PL opportunities. The main reasons for their lack of participation included: not being aware of STEMShare Professional Learning programs, being time poor, and having enough prior knowledge.

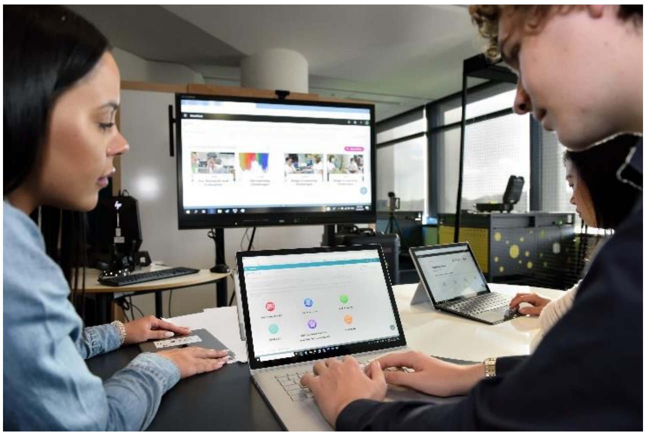


Based on the research findings, we make the following recommendations:

- ✓ Given the observed lack of improvement in girls' STEM self-efficacy, this research calls for developing STEM learning activities and challenges that provide girls with the opportunity to collaborate, to create things and to solve real-world problems using STEM technology. This argument is based on prior research that shows what attracts girls to STEM are collaborative learning activities that involve innovation/creativity, building things, and practical/real world applications (Koch, 2002; Mertz & Atwood, 2012). The more opportunities girls have for effective STEM activities, the higher their STEM confidence and self-efficacy, and the more positive their STEM attitude will be (Goodyer, & Soysa, 2017).
- ✓ stem.T4L Professional Learning was the main factor contributing to teacher readiness to implement STEM technology, as indicated by teachers. However, teachers also identified the contribution of other factors including school climate, their own knowledge, confidence and passion, and students' active participation. This finding suggests the centrality of effective PL to inform, instruct and equip teachers with the right knowledge of STEM technology integration. Yet it also foregrounds the role of school leadership in creating an environment of support and collaboration amongst teachers and assisting teachers especially

with the technical difficulties they might face. In other words, STEM integration cannot be treated as a stand-alone work but it inevitably entails an equal engagement of all the parties involved including school leadership. Another key factor to consider is teacher-self. Teachers need to be fully on board with the idea of STEM integration, and appreciate and acknowledge the contribution of STEM education and be engaged with upskilling and improving their knowledge of STEM technology. There is no doubt that teacher enthusiasm, knowledge and confidence transfer to students. Hence to maximize student participation in and engagement with STEM, we need to have emotionally and mentally engaged teachers in STEM.

- ✓ 20% of teachers who participated in this research did not undertake any stem.T4L Professional Learning. The majority of these teachers cited "lack of awareness of PL opportunities" as the main reason. Since its launch in 2018, the stem.T4L Project has reached over 1,206 schools across NSW and approximately 15,000 teachers have participated in online and face-to-face workshops and events. However, based on the data collected for this research it appears communications regarding PL opportunities could be further improved to ensure all participating teachers in stem.T4L Project are fully aware of the opportunities on offer.
- ✓ Time constraints proved to be a challenge for teachers when it came to integrating STEM technology and participating in PL events. Being time poor takes its toll on teacher collaboration and reflection as well. One way to address this challenge is to offer adequate release time to teachers to meet with other teachers, discuss their STEM experiences, reflect, conduct careful planning, and engage in available PL events.
- ✓ There were a number of technical challenges discussed by students and teachers regarding implementing the kits in the classroom. In particular, 10% of students mentioned that they used stem.T4L equipment "only once" because of technical issues which, in some cases, remained unresolved for several weeks. Technical difficulties caused feelings of frustration and dissatisfaction across the two groups of respondents. Recruiting more stem.T4L leaders on the ground to provide relevant and contextual support to teachers could address this problem and lead to higher satisfaction and wider application of the equipment.
- ✓ How-to videos (36.30%) and Learning Library resources (29.79%) were the most highly used form of PL, while participation in face-to-face PL was slightly low (17.81%). Although online PL appears to be more feasible and can address teachers' immediate needs, teachers are encouraged to participate more in face-to-face learning as the collaboration that occurs between teachers has widely reported benefits (Bates, Phalen, & Moran, 2016). However, the low rating of face-to-face PL participation might also indicate that the opportunities offered were limited, compared to online learning. As such, this research calls for



more on-going and long-term face-to-face and one-on-one PL support to increase teachers' knowledge and confidence in STEM technology integration.

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