NSW Department of Education

stem.T4L

An overview of the research on the stem.T4L project: A three year journey

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Technology for Learning Portfolio
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Introduction

Since the start of the stem.T4L Project, ongoing research has been carried out to measure the impact and effectiveness of the program in diverse NSW school settings. The project has produced eight reports, two literature reviews (one conducted externally), and a podcast series of three episodes (330 listens to date) presenting the research findings (Figure 1). The research conducted thus far has measured students' and teachers' stem.T4L experiences across a range of metrics including the extent to which it has positively impacted and improved (1) teachers' confidence (self-efficacy beliefs[1]) and competence in teaching using STEM technology, (2) their attitudes of and interest in STEM education, (3) their engagement in online STEM Communities of Practice (CoP), (4) students' 21st century skills, (5) students' learning outcomes, (6) students' aspirations for STEM careers, and (7) female students' STEM interests and motivations. Figure 1 depicts periodic reports produced based on the research undertaken on stem.T4L.

1 Please note teacher self-efficacy beliefs and teacher confidence are used interchangeably in this paper.

Figure 1. stem.T4L Research published on the Learning Library

Report	Data sources	Date
Immersive virtual reality, children and school education: A literature review for teachers.	Review and analysis of emerging research on IVR. Conducted externally by A/Prof Erica Southgate, University of Newcastle	May-2018
stem.T4L Project (Pilot study): Lessons about improvements to self-efficacy, attitudes, and interest in STEM learning	Teacher/student surveys Teacher focus group interviews	Sep-2018
A Literature Review of K-12 STEM Education	Systematic analysis of STEM literature	Dec-2018
Term 4, 2018: Observations and insights from the research on the contribution of a state-wide STEM Project	Teacher/student surveys Teacher focus group interviews	Apr-2019
Improving students' 21st century skills through the stem.T4L Project (Podcast available)	Teacher/student surveys	Jul-2019
Creating a sustainable STEM Community of Practice (Podcast available)	Social media analysis of postings by teachers, stem.T4L admins and leaders	Sep-2019
The impact of stem.T4L technology on students' STEM career aspirations (Podcast available)	Student surveys	Apr-2020
stem.T4L in NSW High Schools: Building immersive, creative and engaging learning experiences	Student surveys	Nov-2020
Does stem.T4L improve student learning outcomes? Evidence from teacher survey and school case studies	Teacher surveys School case studies Teacher interviews Individualised learning journeys	Apr-2021
IVR as a tool to create digital art: The case study of Blacktown Girls High School's engagement with stem.T4L	Student surveys Classroom observations Teacher interviews	Aug-2021

Figure 1. Published research reports on stem.T4L

The overall methodology adopted in these studies used a mixed-methods approach employing pre-post surveys, focus group interviews, social media analysis, and school case studies involving classroom observations. An impressive number of responses have been collected to date through our term-based pre-post online surveys, with approximately 10,000 responses from students and 3,000 from teachers. Apart from large-scale survey methods, three exploratory case studies were conducted, one in primary schools and two in secondary schools, to obtain an in-depth understanding on students' and teachers' learning and teaching experiences with the stem.T4L Project. An additional 13 groups of teachers and 56 students participated in focus group interviews conducted for the case studies. A social media analysis of over 2,600 postings was also performed to explore the potential of an online stem.T4L Community of Practice for collaborative learning and online support.

This report outlines the key findings of the research on stem.T4L over the course of three years, from its inception with the pilot study to its current development.

stem.T4L: Outcomes for Teachers

1 **Significant improvements** in teachers' STEM confidence and competence

2 **Sustained satisfaction** with stem.T4L Professional Learning

3 **Increased teacher collaboration** through developing a STEM Community of Practice

Finding 1: Significant improvements in teachers' STEM confidence and competence

To rigorously evaluate the benefits of stem.T4L for teachers, we examined teacher development in four aspects at two time points; before and after their engagement with stem.T4L. The variables under study included Interest and Attitudes towards teaching STEM, and Confidence and Competence in using STEM technology for teaching and learning. It was hypothesised that implementing stem.T4L equipment and access to ongoing online and face-to-face support and Professional Learning (PL) available to teachers, would lead to teachers' higher self-assessment of the variables under study, conveying their enhanced capabilities and professional growth.

A baseline Teacher survey was sent to 1,500 schools over four school terms and was completed by 1,850 teachers at pre and 609 at post[2] stages. The statistical analysis conducted on the aggregated data suggested that teachers maintained similar enthusiastic attitudes and interest in teaching STEM between pre and post-tests, across four study periods, as indicated by an aggregate of 98% for Attitudes towards STEM in both pre and post-tests; and 96% (pre) 98% (post) for Interest in teaching STEM. However, significant improvements were observed in teachers' Self-efficacy beliefs and Competence in using STEM technology. Compared to Interest and Attitudes, teachers' STEM Self-efficacy beliefs and Competence were moderately low and consistently averaged at 77% and 60% respectively, at the outset of each school term. The baseline qualitative data supported this observation, as a large number of teachers clearly articulated their lack of confidence in using the stem.T4L equipment in their commentaries. Interestingly, teachers even identified their own lack of STEM knowledge and low confidence in working with technology as the main barriers to using the stem.T4L kits. They felt "anxious", "scared", "nervous", "overwhelmed", "uncomfortable", and "worried" as they had limited knowledge of STEM technology.

The impact of implementing stem.T4L equipment, receiving ongoing professional and technical support, and having easy access to an online Learning Library, where additional resources and tutorials were available, manifested themselves in a statistically significant difference in teachers' sense of confidence and competence. The aggregated data from the follow-up surveys collected from 609 teachers showed that teachers' self-efficacy rose by approximately 16% and their competence grew by 21%.

2 The number of teachers returning the post-surveys was usually significantly lower than the pre-survey respondents, which continued to be an inherent limitation of all the research we conducted.

Teacher confidence and competence are positively associated with student achievement. In other words, teachers with higher levels of STEM confidence are better positioned to apply STEM technology and more equipped to steer students' interest and motivation towards STEM and enhance their STEM learning outcomes. As such, we postulate that by improving NSW teachers' STEM self-efficacy beliefs and abilities, the stem.T4L Project continues to create a substantial positive impact on teachers' readiness to employ STEM technology in innovative and interactive ways across diverse disciplinary fields. Figures 2 and 3 show the overall growth of teachers' STEM self-efficacy beliefs and competence over four research cycles.

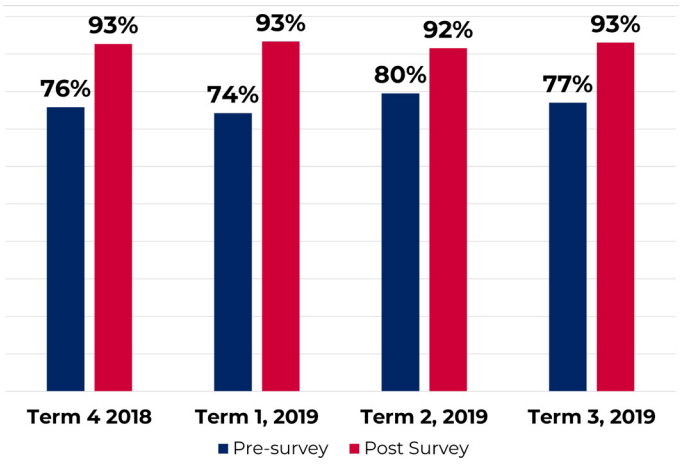


Figure 2. Growth in Teachers' confidence in using STEM technology

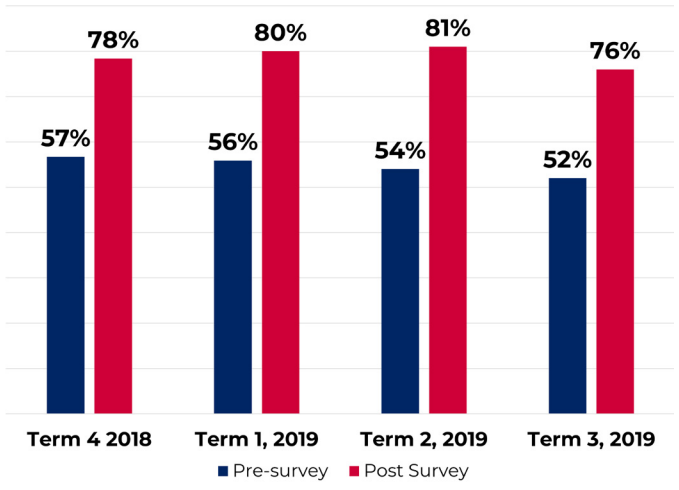


Figure 3. Growth in Teachers' STEM Teaching Competence

Finding 2: Sustained satisfaction with stem.T4L Professional Learning

Teachers' feedback and evaluation on PL opportunities, offered as a key component of the project, was continually measured through quantitative and qualitative methods. In total, 885 teachers responded to PL related items in the post-surveys and rated their satisfaction with PL opportunities consistently over 85% across five research cycles, as shown in Figure 4.

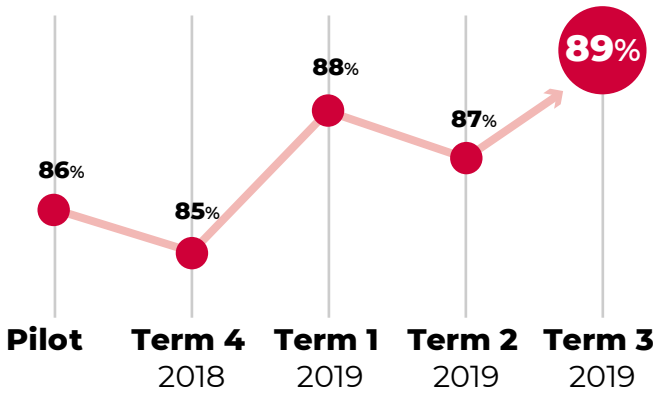


Figure 4. Satisfaction with stem.T4L PL

One of the most praiseworthy components of the PL, according to teachers, was the array of resources and learning materials available on the Learning Library, with at least 85% of surveyed teachers in each term attesting to the positive impacts of the learning materials on their professional development. The data measured across four school terms, also suggested that stem.T4L was successful in encouraging collaboration amongst teachers, with 75% of teachers confirming that STEM collaborations increased at their school following their engagement with stem.T4L. Figure 5 shows teachers' level of agreement with the contributions of PL to a number of key areas, which had resulted in a higher uptake of stem.T4L equipment and teachers' engagement with the project.

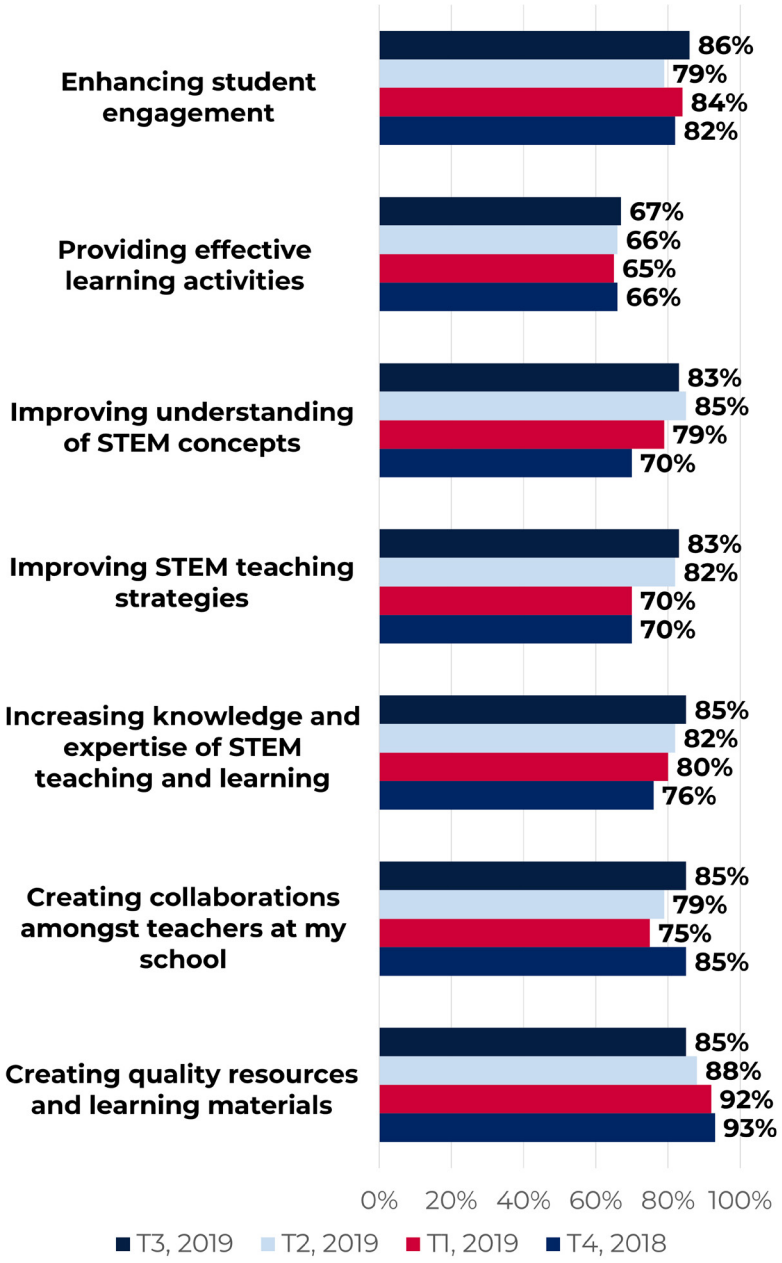


Figure 5. Teacher agreement on the contibutions of stem.T4L PL to a number of key areas

Finding 3: Increased teacher collaboration through developing a Community of Practice

Research findings indicated that teachers benefited immensely from collaborative engagement, which we identify as a "Community of practice". Shortly after the launch of the stem.T4L Project in 2018, social media groups were created on Facebook, Twitter and Yammer to provide teachers spaces to collaborate, share experiences, and support each other. We explored teachers' involvement in stem.T4L social media groups between January and June 2019 to examine the extent to which teacher learning was taking place within this online space. We found that stem.T4L social media was functioning as an effective online STEM CoP, and that the community was showing signs of being a collegial and productive platform for teachers' professional learning. More importantly, 55% of the total postings were classified as 'Active Learning' (Figure 6). This finding suggested that the members used stem.T4L online groups as an opportunity to receive informal professional learning, where they could remotely connect to other educators to

solicit advice, share their classroom experiences, and engage in collaborative problem solving. Also, as Figure 7 indicates, 'Socialising' was the most frequent type of use (33%), where members offered each other encouragement or general support. Problem-solving was the second most frequent use of social media, indicating that 24% of postings involved members offering solutions to technical problems or responding to requests for creative and pedagogical suggestions.

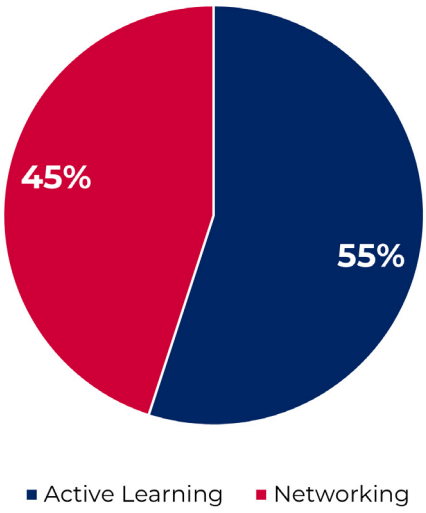


Figure 6. stem.T4L Community of Practice

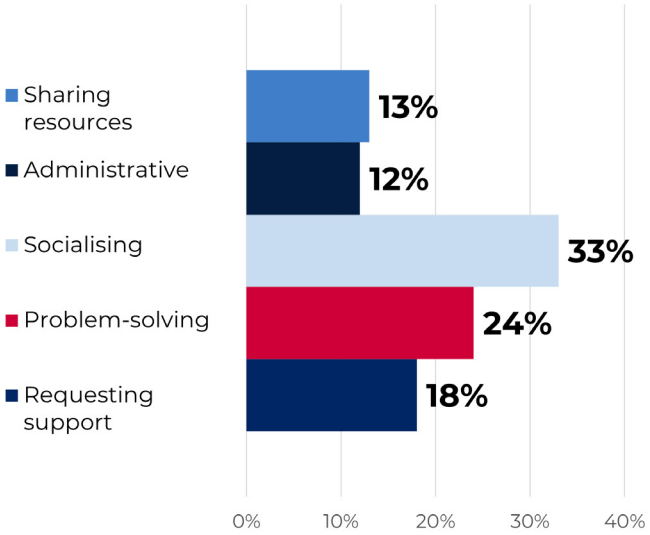


Figure 7. Professional use of stem.T4L social media

stem.T4L: Outcomes for Students

1 **Improvements** in 21st Century skills

2 **Higher** STEM career aspirations

3 **Improved** creativity and collaboration amongst secondary students

4 Female students' **increased likelihood to pursue STEM** career pathways

5 **Improvements** in student learning outcomes

Finding 1: Improvements in 21st century skills

One of the areas where stem.T4L has created a statistically significant difference is in students' 21st century skills and capabilities. Put differently, exposure to stem.T4L technology has enhanced primary and secondary students' self-perceived collaboration, creativity, higher-order thinking skills, problem-solving abilities, and leadership. In Term 1, 2019, a survey designed to capture students' perceptions of their 21st century skills, was sent out to schools before and after their engagement with stem.T4L. The data was collected from 2,151 students at baseline and 799 students at follow-up. As Figure 8 shows, students had a higher evaluation of their 21st century capabilities by the end of the project, with improvements observed across all skills. Working with the equipment had the greatest impact on students' problem-solving skills, communication, and leadership as they had the highest growth (6%), compared to other capabilities, between pre and post evaluation.

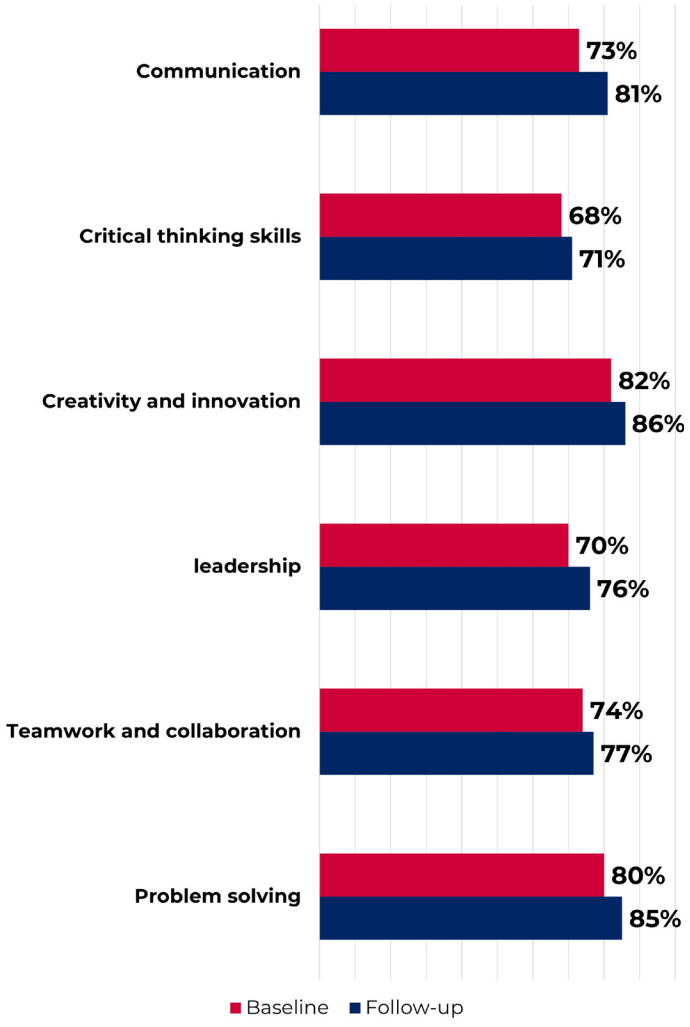


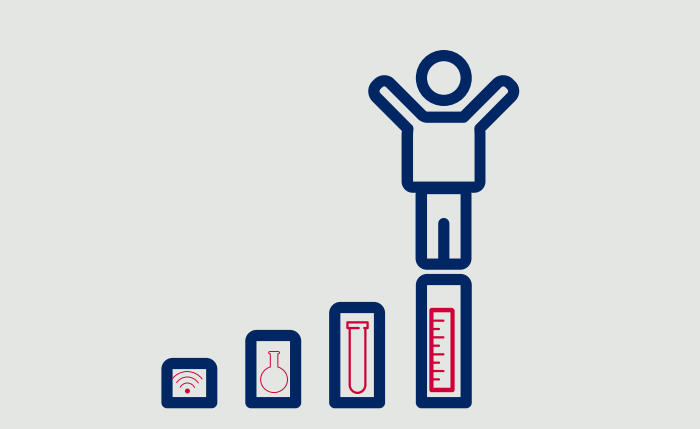
Figure 8. Students' self-perceived 21st century skills at baseline and follow-up

Finding 2. Higher STEM career aspirations

In the study conducted in Semester 1, 2019 on 3,494 students (80% primary and 20% secondary), we found that only 45% were interested in STEM fields before their participation in the project, while 51% opted for non-STEM jobs, with artistic and creative careers attracting the highest interest from students. An increase by 5% was observed in students' STEM interest level by the time of the post-test (n=1,478), where 55% agreed that there was a change in their perspective towards STEM and their likelihood to choose a STEM career, after they worked with the stem.T4L equipment for one term. The commentaries provided by students suggested that by the end of the term students grew more cognisant of the significance of STEM fields for their future lives and professional prospects, and this renewed appreciation for STEM contributed to their increased interest towards STEM fields.

Finding 3. Improved creativity and collaboration amongst secondary students

Research conducted in the first two years of the project reflected the need for more concentrated effort on collecting data from secondary schools, where the participation rate in stem.T4L studies was only 10%. Focus group interviews were held with six secondary schools that booked stem.T4L kits in Term 3, 2020. A total of 40 students and seven teachers came together to share their impressions and experiences of working with stem.T4L in a virtual face-to-face interview. In addition, pre-post online surveys were sent out to all secondary schools participating in stem.T4L in Term 3, 2020. A total of 503 student responses were received in the pre-survey, out of which 185 students responded to the post-survey. 71% of students who took the post survey provided an overall positive assessment of their experience, which indicated that stem.T4L had the potential to deliver favourable outcomes in the majority of NSW primary and secondary schools alike. When asked about key competencies students believed to have improved as a result of working with the equipment, 89% identified one or more, with 'creativity' and 'collaboration' accounting for the majority of responses. The focus group data further revealed that tangible and concrete learning experiences were facilitated as the equipment was introduced into classrooms, suggesting that stem.T4L had resulted in learning that was not only more enjoyable but more engaging, active, and effective. In some schools, students and teachers reported increased opportunities for self-directed learning, leading to a deeper understanding of core STEM concepts.



Finding 4. Female students' increased likelihood to pursue STEM career pathways

Gender differences were examined throughout the life of stem.T4L to uncover girls' and boys' interaction and engagement patterns with the stem.T4L technology and their potential implications for STEM career pathways. It was found that at the outset, a higher percentage of boys (50%) expressed STEM aspirations than girls (41%). At the time of the post-test, although boys still had a higher likelihood to choose STEM fields (boys 54% vs girls 47%), the engagement with stem.T4L prompted a higher percentage of girls' reappraisal of their abilities to succeed in STEM (girls 6% vs boys 4%). This finding suggested that when provided with opportunities to participate in hands-on STEM activities that promote collaboration, team work, and creativity through exposure to STEM technology, girls are more likely to demonstrate higher STEM interests and aspirations. To obtain an in-depth understanding on female students' unique learning journeys with stem.T4L, we also conducted a case study on a Girls-only secondary school. The school had booked the stem.T4L Immersive Virtual Reality (IVR) kit to use in an after-school art Masterclass.

The qualitative data from focus-group interviews with students suggested that through the real-world application of IVR, students learned to appreciate the various possibilities that technology offered for creating art, which in turn opened up new horizons for them, motivating them to consider career options in the field of technology. The Masterclass learning environment also created ample problem-solving scenarios for participants, dramatically increased student engagement, paved the way for on-going collaboration and teamwork, promoted self-directed learning opportunities, and resulted in the achievement of wider curriculum and syllabus outcomes for students.

Finding 5: Improvements in student learning outcomes

One of the objectives of stem.T4L has been to improve student learning against NSW Syllabus outcomes. A common approach to assessing gains in learning is to measure students' development in two main domains; cognitive and affective. Earlier research conducted on stem.T4L, as represented in findings above, indicated that stem.T4L created impressive results when it came to learning gains in the affective domain (i.e. students' STEM interests, motivations, attitudes and aspirations). In the second semester of 2020, we ran a one-off teacher survey to explore teachers' professional assessment on the effectiveness of stem.T4L for improving learning outcomes in the cognitive domain. The data provided by 408 teachers demonstrated that 94% of surveyed teachers believed the project has had a definite positive influence on student learning. When asked to identify factors contributing to improved learning in a stem.T4L learning environment, teachers discussed opportunities for trial and error; a heightened sense of curiosity among students; opportunities to produce a real-world product, and a stronger and tangible link between different Key Learning Areas (KLAs).

To examine the extent of learning growth further, we conducted a case study on three primary schools; two experimental groups (used a stem. T4L kit), and one control group (school that was not involved in the stem.T4L Project and did not have a stem.T4L kit). Against numerous outcomes, we observed clear progress for students who were using the stem.T4L kits – particularly when compared against the control group. For instance, in Maths, students in both cohorts were at the same proficiency level (Working towards) at the outset of the term. However, students in the experimental group who had worked with the stem.T4L kits outperformed the control group when the final assessment was completed. There was a remarkable increase in the number of students in the experimental group that progressed to the 'Working beyond' category – from 3-4 students at pre-test, this proportion increased to 15-28 students at post-test across four indicators. As another example, in Science and Technology, a strong shift from 'Working towards' to 'Working at/beyond' was observed for students who were using the PC robotics kit to use algorithms to develop solutions (ST3-3DP-T) and when using scientific knowledge and practice to examine living things (ST3-4LW-S).

Conclusions

Key factors in effective implementation of stem.T4L technology

The research undertaken so far highlights the substantial role of a number of factors that affect the uptake of stem.T4L equipment in schools, and subsequently the overall effectiveness of the stem.T4L Project. These factors are grouped under four main categories (Figure 9), with the stem.T4L PL program appearing on top of the list, signifying the important contributions of PL to teachers' sense of readiness to implement STEM technology. In addition, school climate (e.g. collaborations amongst teachers), teachers' underlying assumptions and acceptance of technology, and students' internal motivations for learning, to name a few as shown in Figure 9, warrant sufficient considerations as they have the potential to influence the overall effectiveness of STEM initiatives one way or another.

1. Stem.T4L PL	2. School climate	3. Self	4. Student participation
• Learning Library (e.g. Learning Challenges) • Stem.T4L leaders (face-to-face support) • Online webinars • How-to videos	• Supportive staff and leadership group • Time of the year • Collaboration amongst teachers	• Prior knowledge/ experiences • Digital literacy and confidence with using technology • Passion/eagerness to utilise STEM technology	• Students' background knowledge • Student engagement • Motivation for learning/working with technology

Figure 9. Factors contributing to the impact of stem.T4L

Long term impacts and benefits of stem.T4L

In addition to the comprehensive data we collected during schools' engagement with stem.T4L, we ran a one-off Teacher survey six-months after teachers' first trial of the equipment. The aim of this survey was to explore whether teachers' increased awareness and expertise in working with STEM equipment had acted as a catalyst for schools' further investment and planning for STEM to enhance student learning experiences. In other words, we were interested to obtain insights on the stem.T4L Project's capacity to have sustainable positive impacts on schools' STEM agendas. In total, 151 teachers from 137 schools completed this survey, 85% of which were primary school teachers. The findings revealed that the positive experiences that stem.T4L had generated encouraged 45% of schools to purchase a kit after the trial. Of the 55% that reverted to traditional STEM teaching approaches, 23% indicated that they intended to purchase a STEM kit in the future, with another 67% sitting on the fence; remaining open to the incorporation of STEM technology at some point. That is to say, only 11% of schools appeared unlikely to consider purchasing. The reasons teachers put forward for their lack of motivation to invest in STEM technology was mainly rooted in their school's budgetary constraints and funding provisions.

The quantitative data collected from this survey further suggested that stem.T4L had left behind an enduring legacy; motivating teachers to continue to collaborate with other practitioners on STEM teaching (73%), and take advantage of the stem.T4L PL opportunities (71%), and the Learning Library (64%), as indicated by the percentage of teachers who said they were still enjoying the benefits arising from the project (Figure 10) even after the trial had ended. A large number of teachers that took part in this survey also believed that the impacts of stem.T4L had transcended beyond the confines of a school term to create a sustained growth in students' STEM and non-STEM skills and capabilities including teamwork and collaboration (82%), problem-solving skills (70%), and their overall interest in STEM (92%), to name a few. Figure 10 below, reflects the percentages of teachers who attested to the long-term educational, professional, and technological impacts of stem.T4L on students and teachers alike.

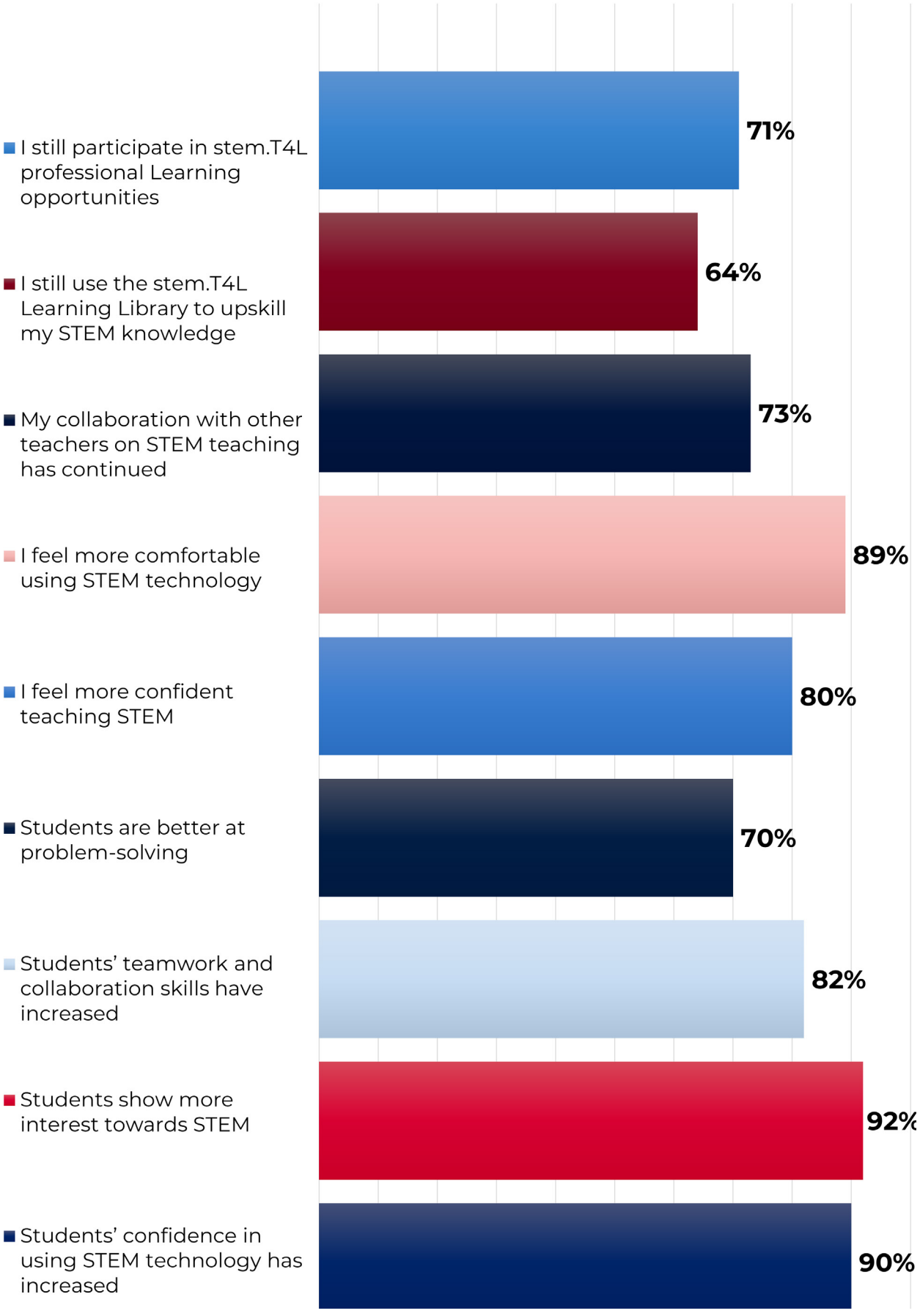


Figure 10. Long-term impacts of stem.T4L on schools

When asked to highlight any other observed long-term benefits of stem.T4L for their school, teachers, first and foremost, acknowledged and praised the unique opportunity they were given to try state-of-the art STEM technology, which had inspired them to reconsider their approach to STEM teaching and learning, as reflected above in the percentages of schools that had either purchased a kit or aimed to do so. Also, in line with the previous surveys data, higher student engagement with STEM, and an increased teacher STEM confidence and knowledge were cited frequently as the by-product of engaging with stem.T4L. Figure 11 outlines the main themes identified by teachers as the long-term benefits of the project, and the frequencies of their occurrence in teachers' commentaries.

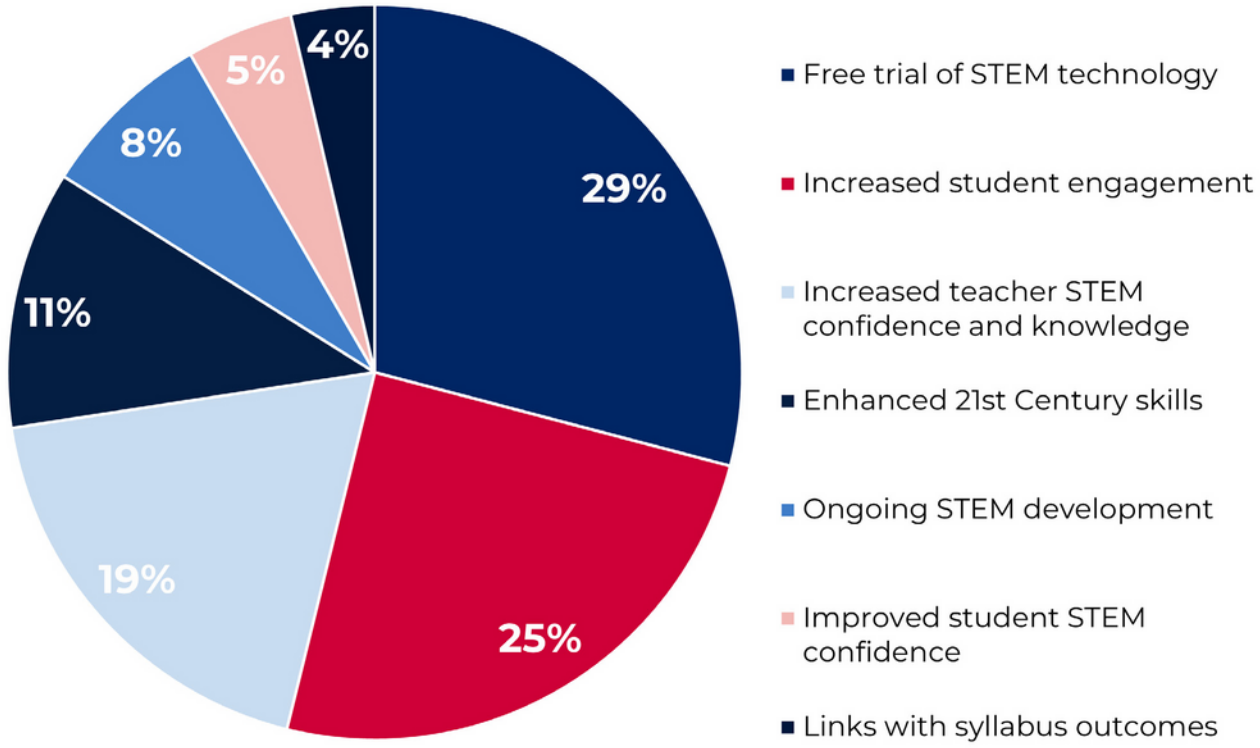


Figure 11. Benefits of stem.T4L for schools

Concluding Remarks

The findings drawn from ongoing research on the stem.T4L Project are promising and allude to its beneficial and multi-faceted influences, both immediate and far-reaching, upon schools. The extensive data illustrates that the novelty of stem.T4L does not wear off after the trial of the equipment. Rather, the implementation of stem.T4L technology, coupled with the availability of PL opportunities, ripple emotional and intellectual excitements, transform classroom dynamics, and create a much-needed boost in confidence within teachers and students; all of which enable them to explore and advance their technological capabilities and apply increased innovations in the ways STEM is taught and learned.