stem.T4L

Stem.T4L in NSW High Schools: Building immersive, creative and engaging learning experiences

This report explores the impact of the stem.T4L project within the specific setting of NSW public High Schools. A pre-post survey design and focus group interviews captured the voices of this cohort and explored their experiences with the stem.T4L kits during Term 3, 2020.

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Author: Dr. Rose (Mahsa) Izadinia and Dr. Matt Johnson
Email: stem.T4L @det.nsw.edu.au

Technology for Learning Portfolio
Information Technology Directorate
NSW Department of Education

TABLE OF CONTENTS

EXECUTIVE SUMMARY

Since its inception in 2018, the stem.T4L project has achieved strong results for schools across New South Wales, by increasing teachers' technology capabilities and raising students' interests and aspirations in STEM learning – as demonstrated in previous research studies. Over two years, the online surveys administered to NSW schools reached over 8,000 students and 2,000 teachers. However, the breakdown of respondents by school types highlighted the fact that 90% of the surveys had been completed by primary students, which called for further research on High Schools.

In this report, we measure the impact of this project within the specific setting of NSW public High Schools. Using pre-post survey design and focus group interviews, we recorded the voices of this cohort and explored their experiences with the stem.T4L kits during Term 3, 2020. 503 High School students took the pre-survey at the outset of Term 3, of which 185 completed the post-survey at the end of the term. To capture more in-depth data, we held focus group interviews with six High Schools that showed willingness to participate in our research. 40 students and seven teachers shared their ideas and experiences with us in virtual face-to-face interviews between week 8 and 10 of Term 3.

The findings of this research shed light on the impacts and benefits for High School students after using the stem.T4L kits, including:

1. 71% of students who took the post survey indicated that they had an overall positive experience working with the stem.T4L kits, indicating that the project had attained notable success in delivering positive experiences in the majority of High Schools surveyed.

2. Despite students' favourable impressions and evaluations of their one term journey with the stem.T4L kits, the statistical analysis suggested no discernible impact on the variables under study (i.e. STEM interest, self-confidence, attitudes, future career aspirations), with all ratings remaining unchanged from pre- to post-evaluation.

3. When asked about which competencies they believed had improved as they worked with their kit, 89% of students were able to identify one or more, with creativity and collaboration accounting for the majority of responses. Previous data collected from primary students yielded the same results where they self-perceived their creativity and teamwork to have grown by the end of their experience with the stem.T4L kits. Based on the findings of our research, we argue creativity and teamwork are two main corresponding skills that implementation of stem.T4L equipment cultivates in students.

4. The focus group data revealed significant contributions of working with the stem.T4L kits to student learning and engagement. Tangible and concrete learning experiences were facilitated through use of the stem.T4L kits, which also resulted in a learning that was more enjoyable and easier. In some schools, students and teachers reported increased opportunities for self-directed learning, leading to a better understanding of learning concepts especially in STEM.

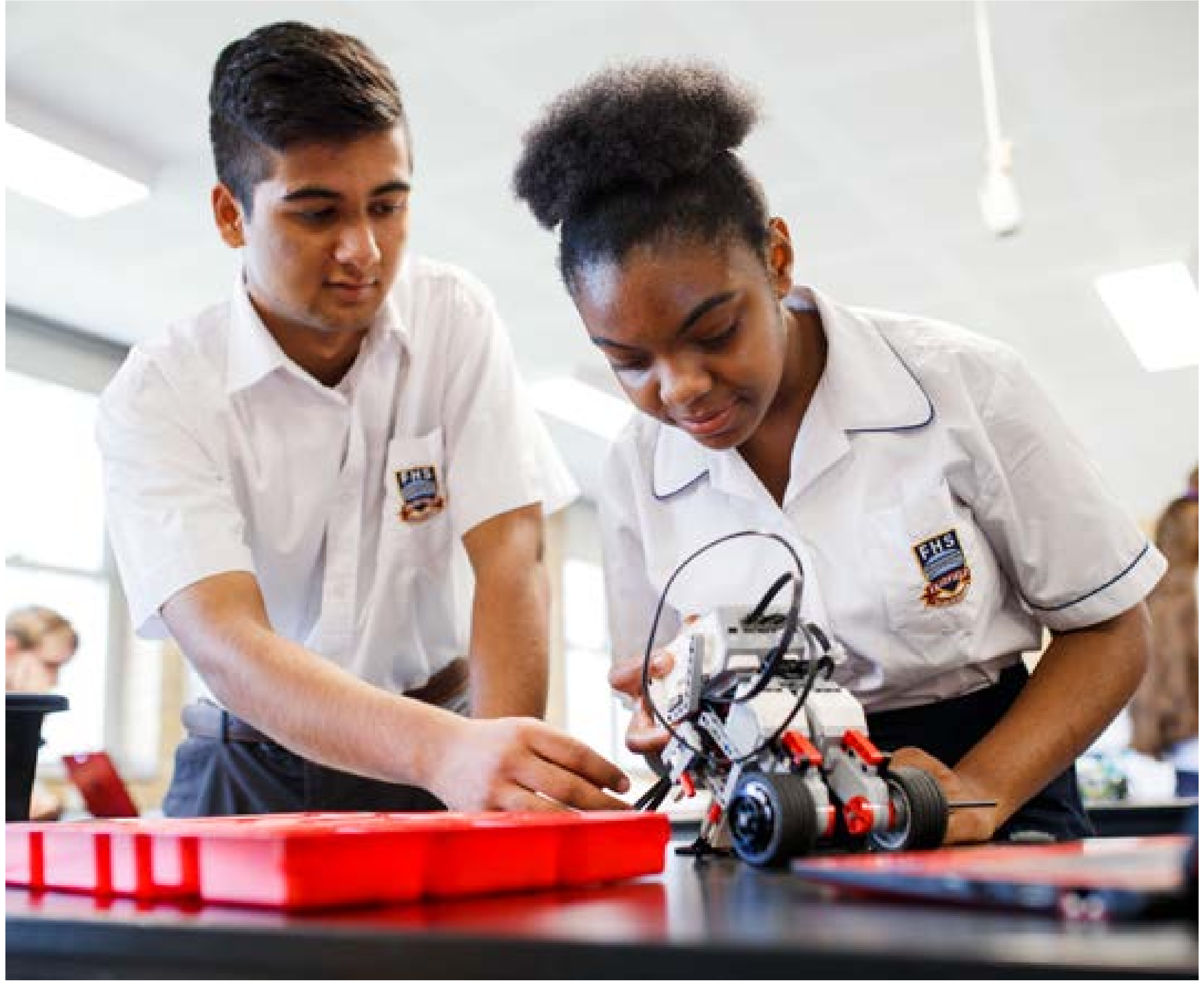
5. The analysis of the survey and interview data revealed challenges and shortcomings that, we argue, might have contributed to the lack of observed improvement in student variables. These factors included: (1) teachers' lack of substantial investment in planning and designing relevant learning activities, (2), already crowded lesson schedules (3), lack of collaborative teaching exercises, and consequently (4) limited opportunities for students to use the technologies

The pedagogical implications and recommendations for teachers and the project group are discussed in the report's closing section.

BACKGROUND

What happens behind the school walls, where the educational experiences are crafted and delivered, drastically shapes students' mindsets of what is interesting and worthwhile. It is those moments of effective engagement with school activities, the sense of achievement gained, and a growing interest in knowing that ultimately directs students into different career pathways. Although every school year is woven into the fabric of who students are and will become, High School remains a more crucial time for students, as they start to think about their future career tracks. As Cuny states, High School is a time when students begin to "explore individual disciplines in depth, begin to seriously consider career paths", and start preparing for tertiary study or employment (2012, p. 34).

Research on High School experiences and how they influence students' career choices suggests an ongoing interest in this space. Much work has been done by researchers who have focused on STEM education, with important findings revealing the interplay between positive experiences and interest in STEM in High School and future STEM careers. A study from Romania, for example, shows that 96% of respondents who chose a STEM field had graduated from a High School where they studied sciences intensively, and 70% of respondents viewed their experience with mathematics and science at High School as positive (Popa, & Ciascai, 2017). Another line of research from the US provides evidence on a definite link between educational experiences and earning degrees in STEM, such as "the amount of class time spent engaged in specific activities", students' "level of interest in specific subjects", and "how challenging they found the material" (Maltese & Tai, 2011 p. 886). In general, there are many researchers who reason that the type of STEM experiences students receive in their classes have a major influence on who remains and who leaves STEM (Cleaves, 2005; Maltese & Tai, 2011; Wang, 2013).



Although somewhat dated, Woolnough's (1994) work lends insights into the research on High School experiences, particularly on factors affecting student decisions to continue in science. Woolnough observed that factors such as stimulating lessons and linking content to everyday life positively affected classroom experiences. In an attempt to create stimulating STEM lessons that engage students and ignite interest, and in order to make STEM content more relevant to student life, researchers and educationalists have tried to integrate technology and engineering into the curriculum as a hands-on and minds-on collaborative approach to learning (Kennedy & Odell, 2014). Effective use of new educational technologies (e.g. robotics, 3D printing, virtual reality) has repeatedly proven to enhance students' learning experiences and produce positive outcomes such as improved understanding of STEM concepts and development of critical thinking and problem solving skills (Hayden, Ouyang, Scinski, Olszewski, & Bielefeldt, 2011; Kwon, 2017; Lacey, 2010).

The stem.T4L project is an initiative from the NSW Department of Education that endeavours to enhance student learning experiences by tapping into STEM educational technology in K-12 schools, thereby sparking interest in STEM and, ultimately, encouraging student entry into STEM fields. The ongoing research conducted on this project has echoed the findings of previous studies (e.g. Hollenbeck & Fey, 2009) that suggest technology-integrated lessons are "a fun way" for students to engage in STEM lessons. Moreover, we have observed changes in attitudes, deeper appreciation and awareness about what STEM can do, and an increased confidence in working with technology on the part of students and teachers engaged with this project. On a term-by-term basis, we have collected data from online pre- and post-surveys that records the perceptions and voices of over 8,000 students and 2,000 teachers. However, the pendulum may have swung too far towards primary schools, with 90% of online surveys completed by primary students so far. This has been caused, in large part, by the ease with which a primary school teacher can administer a survey to a group of students they teach for an entire day – in contrast to the way High School teachers will work with students on a period-by-period basis and the subsequent time constraints for survey research.

The disparity observed in the research participation rate of primary and secondary students formed the base for the current study, in which we focused our attention on all NSW public High Schools that had booked a stem.T4L kit in Term 3, 2020. To collect comprehensive data we collated two data sources: online surveys, and focus group interviews with High School students and their teachers. The questions and variables measured by each data source, the research participants, and the main findings are discussed in the next section.

The following questions guided the data collection and analysis of the findings:

1. To what extent was the stem.T4L project a positive learning experience for High Schoolers?
2. Did participation in the stem.T4L project improve High School students' perceptions relating to STEM learning, such as their levels of interest, confidence and digital resilience?
3. What was the biggest impact of stem.T4L on High School students learning experiences?

DATA COLLECTION

Online Surveys

Pre and post online surveys were administered at the outset and at the end of Term 3 to collect data from High School students. Both surveys included almost identical items and used a five-point Likert scale format for most questions (from 1 = 'strongly disagree' to 5 = 'strongly agree'). Except in the case of negatively worded items, higher agreement with the items would suggest a more positive response.

Students were asked to provide an ID (i.e. first name and last name initial), which remained confidential throughout the research process. At the end of Term 3, once the post-survey was closed, the pre and post data was matched using the students IDs to identify those who had completed both pre and post surveys. This screening resulted in a sample consisting of 185 students with pre and post surveys completed. Linking participants' responses from the pre with the post offered a more reliable and systematic statistical analysis, which helped us discern changes in the variables under study more clearly.

As Table 1 shows, 503 responses were collected from the pre surveys, with boys (58%) and Year 7s (27%) accounting for the majority of responses. 228 students completed the post survey at the end of Term 3, 2020, of which 62% were male. Year 7s similarly had the greatest participation rate (28%) compared to other year groups at the time of the post-test. As mentioned above, to achieve the highest reliability of the data, we included only those students who had completed their pre and post surveys (n=185). However, for the items that were unique to the post survey – such as the rating of the stem.T4L, and the impact of the kit on skill development, which will be discussed below – we included all responses (n=228).

Table 1

Pre-Survey	Post-Survey
Total= 503	Total= 228
Male: 58%	Male: 62%
Female: 42%	Female: 38%
Y7: 27% Y8: 26% Y9: 13% Y10: 22% Y11: 9% Y12: 4%	Y7: 28% Y8: 21% Y9: 13% Y10: 37% Y11: 0.44% Y12: 0.00%

Table 1. Breakdown of pre and post surveys responses

Interviews

In order to reduce survey attrition (drop-out that occurs towards the end of long surveys) and ensure a higher completion rate in the online surveys, we avoided open-ended items, and instead focused primarily on multiple-choice questions. However, more in-depth data was required to obtain students' first-hand experiences with the stem.T4L equipment and resources, where a number of students could discuss and share their viewpoints with their peers. As such, we designed a one-off semi-structured focus group interview for teachers and students that had a stem.T4L kit in Term 3. We were mindful of the fact that each kit (e.g. Immersive Virtual Reality, PC Robotics, and Handheld Virtual Reality) could create different learning experiences or promote different sets of skills and competencies, which could shape students' perceptions and understanding of STEM learning to varying degrees. Hence, we approached one school per each kit initially, while factoring in their locations to accommodate geographically dispersed participants. However, given that the majority of High Schools had Immersive VR (37%) and Handheld VR (29%) in their possession in Term 3, we were somewhat limited by the number of schools that had a PC Robotics (7%) or a Coding kit (12%). After making initial contacts with schools, it was clear that not all had managed to use their kit in Term 3 and therefore they were not willing to participate in our research – another factor that influenced the selection of schools.

Six High Schools expressed their interest in participating in our focus group interviews, as Table 2 below shows. A meeting was organised with the participating teachers to discuss the procedures of the research. All interviews were conducted online via Microsoft Teams or Zoom due to the restrictions imposed on school visits due to the COVID-19 crisis. In total, 40 students and seven teachers participated in a virtual face-to-face interview between week 8 and 10 of Term 3. In the data that follows, all schools, teachers and students have been de-identified; pseudonyms have been used when participants are directly quoted. Table 2 displays the size of each cohort, their year group, kit usage and the kit types from each of the participating schools:

Table 2

School	School Location	Participants	Stem.T4l kit	Year group	Frequency of kit use
School 1	North-western Sydney	Student: 9 Teacher: 1	IVR	Year 7	Once or twice a week
School 2	Western Sydney	Student: 8 Teacher: 1	IVR	Year 10	Once or twice for class
School 3	South-western Sydney	Student: 9 Teacher: 2	PC robotics	Various (Coding Club)	Once per week, 6 times over Term
School 4	Southern Sydney	Student: 4 Teacher: 1	HVR	Years 7,8 and 9	3-4 times per year group in T3
School 5	South-western Sydney	Student: 9 Teacher: 2	IVR	Year 9	Teacher 1: infrequent. From approx. week 6. Teacher 2: last 6 weeks, twice weekly
School 6	South-western Sydney	Student: 6 Teacher: 0	360° Cameras	Year 8	No teacher data – students didn't give frequency of use

Table 2. Focus group participating schools

The interview discussions focused on topics such as:

- *the benefits of working with the stem.T4L kit equipment*
- *the challenges students faced and how they overcame them*
- *the differences noticed in the learning environment when students had access to STEM technology*
- *and the participants' biggest takeaway from this experience.*

FINDINGS

In our interviews with students and teachers, one of the first questions that we posed related to the implementation of the stem.T4L equipment: how often they used their kit, for which subjects or key learning areas (KLAs), and what the learning activities involved. These stories gave us a clear picture of the journey of the stem.T4L kits in a sample of High Schools in one term, with possible implications about the effectiveness of this experience. Among the six schools that we interviewed, we discerned two patterns of usage. For one group of schools having a kit was more like an exploratory exercise, where teachers had "a bit of a play around with to see what [they] could do with the kit". The other group, on the other hand, took the experience to the next level where they integrated the equipment more systematically and consistently to create content using project-based learning approaches. For instance, it was only around week 6 that a school in South Western Sydney found the chance to use their IVR and, in students' words, they "messed around with it a little bit", and "it was just more playing the game for [them]". However, another teacher in the same school told us that they had the kit twice weekly with their Year 9 students, who had set out on a journey on video production using IVR. Although still early days, the teacher stated that they aimed to build "a true reality roller-coaster or a game or an attraction" in Term 4.

In another school in Western Sydney, students from a Year 10 Graphics class used SketchUp to create 3D models of houses they were designing as part of the optional Architectural Drawing module. They started using the equipment around week four when students had completed their 3D models. They then explored these models using the IVR headsets. The teacher explained that the final plan was for students to use the 3D equipment "to be able to walk through their house that they've designed and just check out the layout and see how it's working". In Southern Sydney Years 7 to 9 students had diverse experiences with their HVR, with one group (Year 9s) using the CoSpaces Edu to build and design an energy efficient house and the other group (year 8s) to create a video game, "aimed at promoting organ donation to students". Another group of students (Year 7s) used the 360° cameras to go around the school and take photos and video footage, with two girls using SITU360 to create a virtual tour of the school to help year 6 students to transition to their school. Similarly, in another school in South Western Sydney, Year 8 students took videos and photos of their designated areas like sporting venues using their 360° cameras. In Term 4, they plan to link those videos and photos to create their own Virtual Reality world.

As evident from the above descriptions, the types of activities and kit usage frequency varied across our focus group samples, with the majority of schools considering Term 4 the time when they could achieve some outcomes. In other words, it appeared that the first term of having a kit served as an introductory course where teachers began to explore the possibilities and strategies for implementing the kit and to try out ideas. A second term of having access to these technologies would mean the plans could come to fruition and students could see palpable results, which would put into perspective the affordances such learning technologies offered.[1]

Despite some schools having limited opportunities to use their kit, respondents described numerous benefits from having the kits in their school. When asked about the biggest impacts or benefits, the interviewees often commented – in quite general terms – about the sheer novelty of using such technology in the classroom. Similarly, their main takeaways often related to the opportunity "to try something new and try something different that they wouldn't normally get to use". Beneath this initial novelty factor – or rather, "the 'wow!' side of it", as one teacher put it – it is clear that participants were describing their excitement at engaging with pedagogies less familiar to them. This was particularly true with teachers and students who had used the handheld or immersive VR kits, and the 360° cameras that allow them to create visual content for VR tours. The sense of being immersed in a virtual world took students beyond the traditional educational confines of classroom and textbook.

1 Under more conventional teaching environments, each school that books a stem.T4L kit will use the kit for one school term, before sending it onwards to a second school. However, due to the disruption caused by COVID-19, schools with the virtual reality kits have had their bookings extended by one term..

Many have reported a palpable sense of 'virtual presence' – the feeling of being transported to an environment they have never been to or to a digital representation of environments they are familiar with (in the case of those schools creating VR content with the 360° cameras):

- *Tom, student: Just the experience, just experiencing VR – you can do stuff that you can't normally do in your life, even more immersive.*
- *An, student: Because with our other learning, you'd write stuff down or you'd look at books and you wouldn't be able to experience the thing that those like scientists could experience themselves.*
- *Natalie, teacher: Actually, a lot of our students also haven't travelled either, so actually taking them traveling around the world on Google Earth...They really got to embrace that experience of where the person that they're researching actually comes from.*

The corresponding effect of these new pedagogies was a visibly heightened level of classroom engagement – this was widely reported by teachers and students, through the use of the kits. Technology here becomes the 'hook' that lures students into higher levels of focus during lessons. Beginning with students, the change in classroom atmosphere was readily apparent to them.

Responses ranged from quite general appraisals of their classmates' enthusiasm – "everyone's eager", one Year 9 boy told us – through to comments that described greater anticipation or long-term engagement for classes involving the kits, such as being more excited to attend such classes. Qualitative data on classroom engagement were often co-related with student perceptions on pedagogy – being "excited" and "[looking] forward to class" were closely related with this "new form of learning". Examples include:

- *Arjun, student: Everyone was engaged with learning and everyone's eager...*
- *Tom, student: People look forward to it... People were more excited to come to class.*
- *Alana, student: It makes you more interested in the subject, because when it's easy to use, then it's a really fun topic. It's just a really engaging way for us to learn.*
- *Hannah, student: Doing it once makes you so excited to do it the next time, because you're really engaged and you're like, "Wow, that was so cool. I can't wait to see what the next VR or the next STEM kit is or yeah."*

When asked about their main takeaways from their experience of using the stem.T4L kits for one Term, most teachers mentioned engagement in some way. The novelty of using this technology for the first time is clearly playing a role in engaging students, by providing a break from other ways of learning. One teacher noted that some of her more disengaged students exhibited levels of focus and attentiveness that were noticeably higher than without the kits. Meanwhile, another teacher described how improved classroom engagement had flow-on effects in terms of rapport between her and her students, largely due to the reduced need for managing "behaviour". For example:

- *Olivia, teacher: All the students in class were engaged with regards to the virtual reality. And some of the students that are disengaged – [usually] only engaged for 10 minutes out of the lesson – were able to go the entire lesson and still be engaged with what was happening...*
- *Natalie, teacher: They really engage with it...It builds a different rapport with the students as well, when you're not just hammering them with content and schoolwork and behaviour.*
- *Marcus, teacher: I think the engagement in using the kit [is the biggest impact] because a lot of the students had never used an immersive VR kit before.*

We explored teachers' and students' perspectives further and the themes that emerged encompassed the impact of stem.T4L on student learning, in terms of learning new skills and knowledge, or finding an increase in students' willingness or ability to engage more with lesson delivery. We will discuss these findings along with other main themes from the interviews in the following sections. Before that we turn to the survey results to have a look at the perspective of the larger proportion of students who rated their stem.T4L learning experience at the end of Term 3.

The evaluation of the stem.T4L experience from High School students' perspective

The interview data painted a positive picture of the learning experiences of six High Schools, characterised by their heightened level of classroom engagement and their noticeable enjoyment and excitement when working with the stem. T4L equipment, as reported by students and their teachers. To capture the voices of the larger cohort (N=228), in the post survey we asked students to rate their overall experience with the kits in Term 3. As Figure 1 shows, 71% evaluated this experience

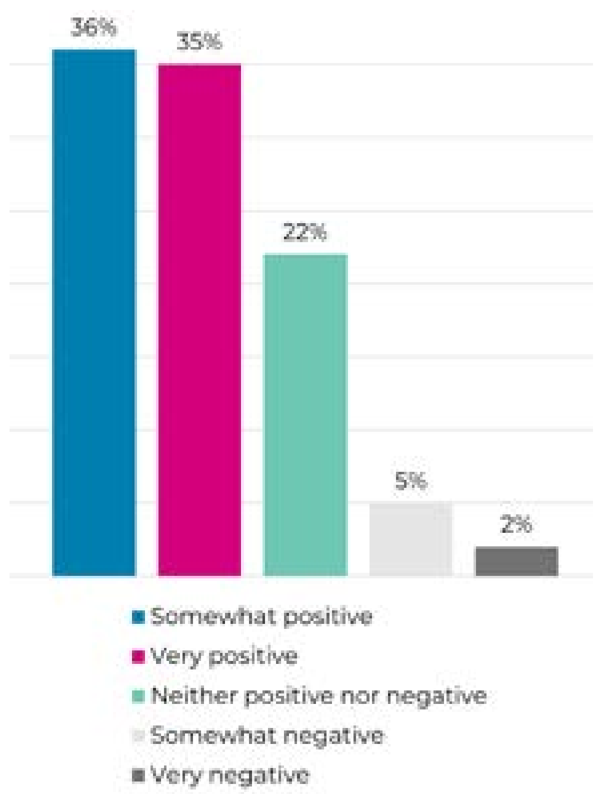


Figure 1. Evaluation of the stem.T4L from student perspective

positively, which is a moderately high satisfaction rate provided by High School students for an STEM-based intervention.

In the introduction of this report, we discussed how learning activities that engage students cognitively and emotionally are key in creating positive educational experiences. Based on students' overall rating and the qualitative data that indicated students found the kits immersive, hands-on, and novel, we conclude that student learning experiences were favourably impacted by the stem.T4L learning technologies. However, for a small proportion – the 22% who took a "Neutral" position, as shown below – the exposure to the kits was of little significance. It was likely that this group of students had limited access to the kits, as their commentaries indicated, which might have affected their rating of the kits to some extent.

Did use of the stem.T4L equipment improve High School students' competencies?

The literature suggests that learning technologies that involve creating, programming, and use of robotics enhance student capabilities in problem-solving, creativity and higher-order thinking skills (Fessakis, Gouli, & Mavroudi, 2013). But what were the skills that our students felt more competent in after trying the stem.T4L technology? In the post survey, we presented the items below and asked students to identify the skills that had been improved following use of the kit. We included an "Other" option to allow for responses that did not fall under any of these categories.

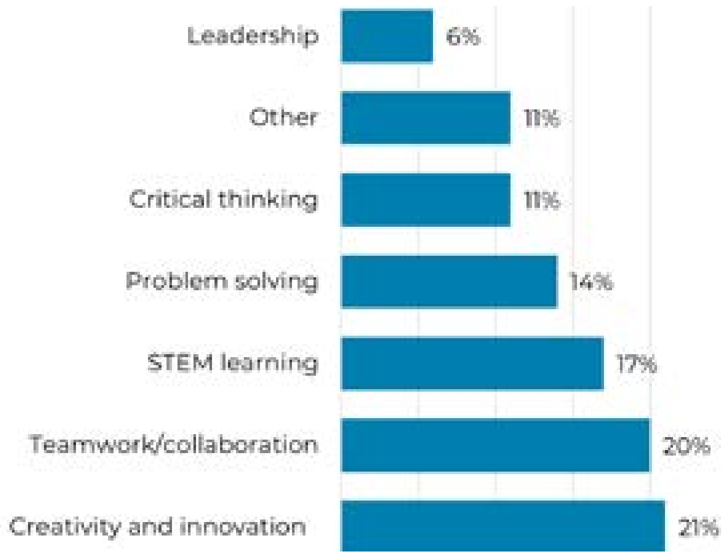


Figure 2. Student self-perceived competencies fostered by stem.T4L learning technologies

As shown in Figure 2, 'creativity and innovation', and 'teamwork/collaboration' accounted for the majority of responses, suggesting that engagement with the stem.T4L equipment had provided the chance for students to think 'outside the box' and collaborate more often. The previous findings from our research on primary school students yielded the same results where they self-perceived their creativity and teamwork to be higher by the time of the post-test (See Term 1, 2019 Report on 21st century skills). These findings echo previous research on educational technologies proposing that students experience higher levels of active learning, collaborative learning, and creativity and innovation in a student-centred learning environment transformed by the affordances of technology-integrated instruction (Byers, Imms, & Hartnell-Young, 2018; Tyler-Wood, Cockerham, & Johnson, 2018).

The focus group interviews shed more light on the collaborative environment that the kits had fostered. Group-based activities with the kits had engendered a greater sense of teamwork and collective engagement with activities than in other lesson plans and structures. One Year 8 boy found that the experience had taught him the value of productive collaboration, and to take the opportunity to find peers he could "actually work well with". Returning to the school that used IVR for testing architectural design, it is interesting that one student noted how different forms of digital technology can make exercises that are ostensibly individual feel far more open and team-oriented. With the VR tour of their designs projected onto the interactive whiteboard, the designer gets to immerse themselves in their design, while their classmates are able to provide feedback and constructive criticism. Further examples include:

- *Christina, student: The class was somewhat more communicative because they were sharing experiences with each other. They were saying how we felt about this compared to that.*
- *Tim, student: We all got to see what we were doing. Like, it's like, in a normal classroom, we're all on our own devices doing our own thing. But like, for these types of lessons, one person is doing the actual VR thing. But we all get to see cause it's projected on a board. We get to help him out and stuff.*
- *Andrew, student: My biggest takeaway would be not just going with your friends and working with your friends. Go with people you actually work well with and you're not just going to mess around, so you actually had the chance to get things done.*
- *Yasna, student: ...And then there was more communication to help each other... everyone was working together to, like, readjust the obstacles.*

- *Natalie, teacher: They all do help each other…so once one of them has the hang of something, they'll all help each other. I think it's really building that collaboration between the students, yeah.*

- *Olivia, teacher: They would have been showing each other how to do particular things on those programs and share any knowledge that they found.*

A relevant question to raise here was whether use of different learning technologies harnessed different skills and broadened the acquisition of certain competencies more than others. Some research studies suggest that, for instance, digital fabrication technologies such as 3D printers can stimulate creativity and innovation more than any other skills (Beyers, 2010; Bull et al., 2017). So, what did the cross-tabulation between the kit types and student competencies indicate? Filtering the data based on the type of the kits yielded interesting results where differences were observed between the kit students used and the skills they believed use of the kit had cultivated, as depicted in Figure 3.

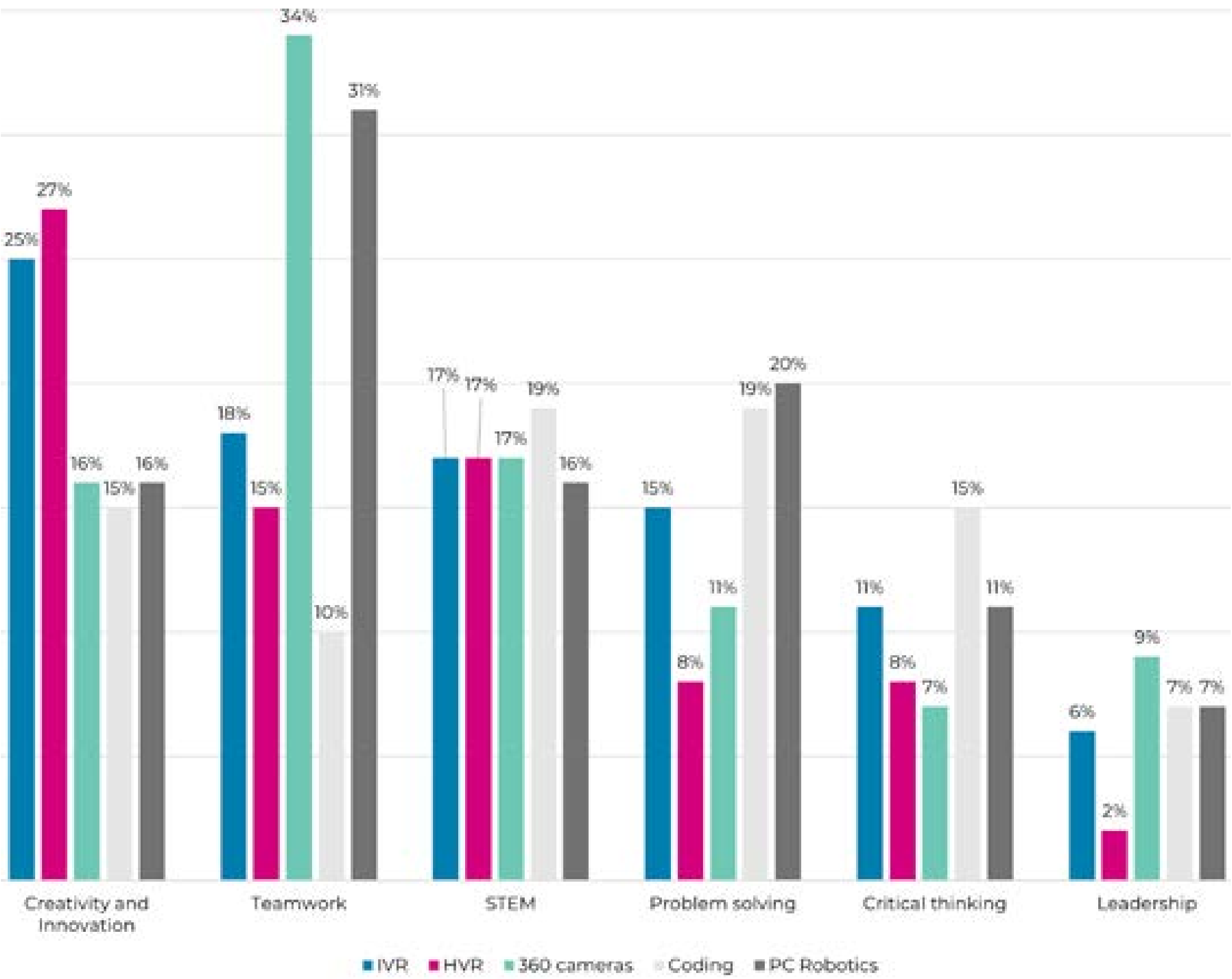


Figure 3. Student self-perceived competencies developed by each stem.T4L kit

HVR (27%) and in the second place, IVR (25%) had promoted student creativity, while 360° Cameras (34%) and PC Robotics (31%) had created more opportunities to collaborate and do teamwork activities more than any other skills. Use of PC Robotics was also linked to development of problem solving skills (20%), along with the Coding kit (19%), although only a small proportion of students used these two kits (N=43). When it came to STEM learning, students believed that all kits had made contributions almost to the same degree, while coding (19%) appeared the most effective tool for learning STEM subjects. The findings lend insights to what capabilities each stem.T4L technology might enable. For example, based purely on students' feedback and perceptions, if problem solving or creativity are the missing elements in a teacher's classroom, the PC robotics and HVR/IVR kits (respectively) might offer opportunities to students to practice these skills. In the examples above, we referred to a school that had implemented 360° cameras to capture photos and video footage of different sports venues in their school. The collaborative effort required to complete the task was abundantly evident from students' responses as in the example below:

- *Ruby, student: My group, we took photos of the quad area, which is like when we hang out at lunch and recess and in our language classes. So we've been practicing, linking videos of us speaking in different languages to our 360° photos.*

Apart from the role of each stem.T4L kit in promoting student competencies, of significance are the learning activities, and how teachers implement such technologies to maximise its impact and effectiveness. For 11% of students, as Figure 2 above showed, using the kits did not improve any skills, as the commentaries provided under the "Other" option revealed:

- *There weren't any skills I could really improve because the only thing we did was looking at information. :/*

- *Nothing we just looked at bad 3d renderings of places.*

- *We really only looked at stuff.*

Although 11% accounts for a small proportion of students, the new learning experience proved "boring" for this group and of little use or relevance, which calls into question the efficacy of the implementation approach. Take HVR as an example, although putting a headset on "does not feel like work", it offers unique experiences and opportunities for learning through the amazing visualizations that it provides, which can never be "lived" (Hicks, 2016). However, the same piece of learning technology could prove disadvantageous if it blocks human communication and the flexibility in learning that different learners require. It is also mundane if teachers implement such technologies without a full understanding of their affordances and how they should be integrated into learning activities to strengthen the link between content and curriculum objectives. It was likely that for a small number of students that crucial link was not established or the frequency of use was not consistent enough to make a meaningful and useful contribution. Hence, the value of such educational technologies – beyond being a tool for entertainment – may not have been fully realised in these students' classrooms.

Stem.T4L kits impact on student STEM perceptions, confidence, and aspiration

As discussed in the method section, the bulk of the pre and post surveys was dedicated to five variables whose improvements are often the focal point of STEM activities and initiatives. These variables included: 1. STEM interest; 2. STEM attitudes; 3. STEM self-efficacy; 4. Digital resilience; and 5. STEM career aspirations.

Interest towards STEM included seven items such as "I enjoy learning about STEM" and "I would like to know more about STEM careers". Attitudes towards STEM had five items including "Most people should understand STEM because it affects their lives" and "We live in a better world because of STEM". These two affective variables (i.e. interest and attitudes) were of significance to us as research suggests students' STEM attitudes and interests are linked with their beliefs in the benefits of pursuing STEM (Baran & Maskan, 2010). Hence, a difference in the ratings of these variables from baseline to follow-up would help us determine the extent of the effectiveness of the project on improving High Schoolers' STEM perceptions and their future STEM career aspirations.

Six items measured STEM self-efficacy. Some of these items were "Science is easy for me" and "I usually give up when I do not understand a STEM concept" (negatively worded item). Student STEM self-efficacy beliefs, defined as students' beliefs about whether they have the ability to succeed in STEM classes and fields, has been researched widely in STEM education (e.g. Deci & Ryan, 2000). High importance has been attached to enhancing students' positive STEM self-efficacy beliefs as a way to maximising student success in STEM (Dubetz & Wilson, 2013). Whether or not working with the stem.T4L kits could create a positive impact on High School students' confidence in STEM was another variable that we investigated in this research.

Digital resilience with seven items included statements such as "When using new technology, I am happy to use trial and error until I figure it out" and "When technology doesn't work the way I want it to, I can look for solutions myself". Digital resilience was the final main factor of interest, measured in this research. By 'digital resilience', we refer to the potential for students to overcome problems or challenges that they encounter when working with digital technologies – this could include using trial and error when learning new apps, researching their own solutions to problematic hardware or 'bouncing back' following the disappointment of an unsuccessful activity. Resilience can have a defining role in students' education (Fernandes, Amaral, & Varajão, 2018). It has been argued that it is the level of one's resilience that determines who succeeds and who fails, perhaps even more so than training and experience (Coutu, 2003). The opportunities that STEM technology provides for technical explorations, filled with trial and error within a safe environment, can foster resilience in STEM. For these reasons, we were interested to track the development of students' digital resilience throughout the term. Changes in student STEM career aspirations was also explored by one item, where students were asked to gauge their likelihood of choosing a STEM career in the future by choosing an option from extremely unlikely to extremely likely.

As Figure 4 depicts (below), the post-survey results did not suggest any improvement in the variables under study.

The achieved outcome was unexpected especially because over 70% of students had evaluated their experience positively and as such one would anticipate some degree of improvement in the post-test ratings.

Variables such as STEM interest and career aspirations were even more likely to experience an increase in their ratings given their studied link with positive learning experiences (Popa & Ciascai, 2017).

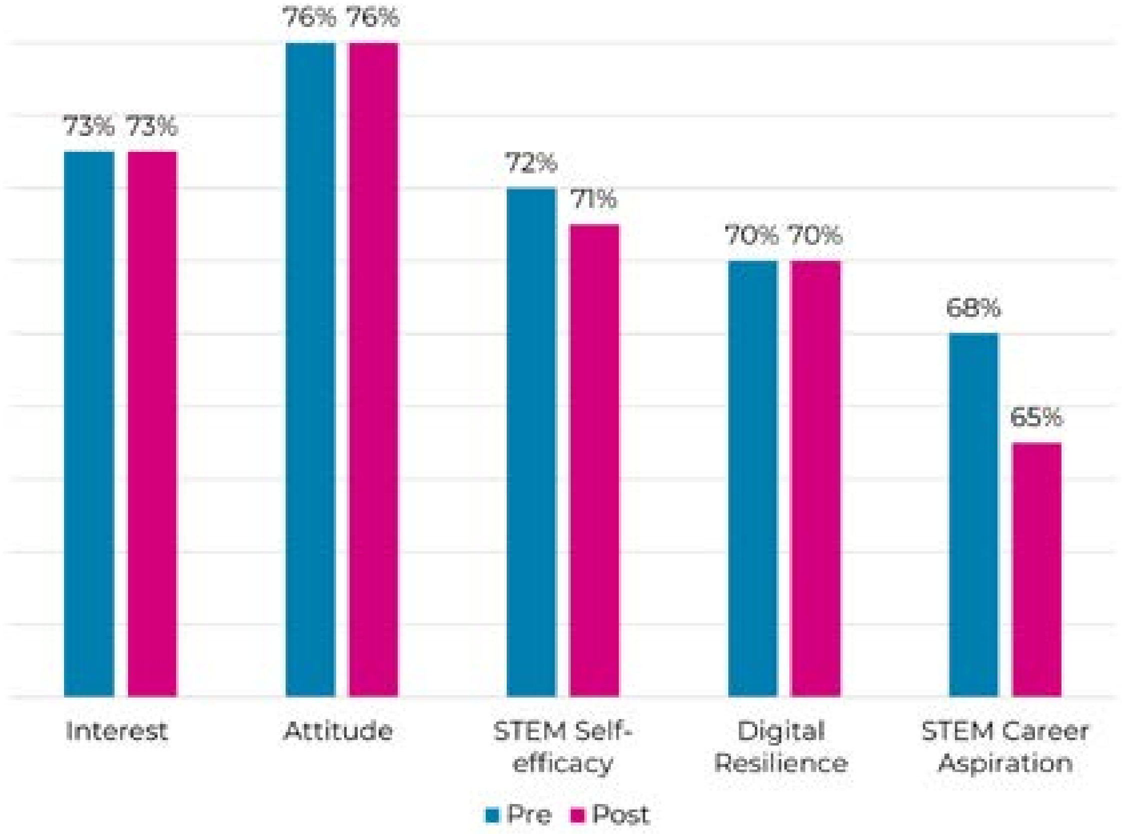


Figure 4. Pre-post ratings of five variables under study

To probe the existence of this potential link further, we filtered the data to obtain the survey results of those who had rated their experience with the stem.T4L equipment only at positive or highly positive (N=160). We hypothesised that the perceptions and interest of this cohort might have improved noticeably compared to those who took a neutral position or considered the experience as negative (N=66). The same analysis techniques were deployed on this new dataset and yet the ratings remained unchanged from baseline to follow-up. Hence, we concluded, although having access to stem.T4L learning technologies had delivered a new and positive experience to students, its impact was not significant enough to create a substantial difference in the ratings of the variables under investigation. One possible reason for this observed lack of improvement might have been "teacher factors", including: the time teachers allocated to exploring and utilising the equipment; the extent to which they made use of the professional learning available, such as the upskilling via the stem.T4L Learning Library resources (e.g. How-to-videos, Learning Challenges etc.), and the extent to which they designed effective and engaging learning activities aligned with curriculum key learning areas. Some researchers argue that careful considerations should be given to the planning, training, curriculum alignment, and resources that should go with technology integration in order to see results (Dror, 2008; Tyler-Wood, Cockerham, & Johnson, 2018). Based on the survey data, we argue that improvement in the above-mentioned variables was potentially compromised by the sporadic implementation of the kits and in some instances, teachers' lack of preparation and readiness to integrate the new technologies (see also, 'Challenges' below).

Although we did not collect survey data to capture teachers' active engagement with the stem.T4L project in Term 3, the focus group data offered some insights that can be compared against the larger survey cohort. In the discussion on their challenges and the key hurdles they faced in integrating the equipment, teachers identified issues which affected the frequency and effectiveness of their kit usage. The challenges teachers reported were quite diverse, with particular issues seeming to effect some more than others. The fact that many teachers were reported being first-time users of these particular kits also introduced a degree of unfamiliarity in their implementation. The impression here is that teachers have already considered how they would do things differently a second time around. Nonetheless, teachers encountered numerous barriers to implementation and effective use, with certain obstacles presenting at different stages of their 'journey' with the kit – from struggling to incorporate the kits into the Term's lesson sequences and programming, to finding that implementation of the kits was hampered by inadequate preparation.

These themes often intersected with a familiar refrain for the modern teacher – a lack of time in their day (or that of their students) – and the subsequently limited capacity for in-depth preparation or sustained classroom use of the kits before the end of Term. A number of logistical or technical challenges were also identified, particularly in regards to setting-up the kits. While not directly effecting the teachers and students in this study, teachers also pointed to barriers they encountered while trying to encourage their colleagues to make use of the kits in their classrooms. These themes are discussed below:

Challenges on the way of integrating stem.T4L equipment

Programming and integration into classwork

Several teachers described the difficulties they had in incorporating the kits into their lesson plans for the Term – this was a factor that they identified when discussing why they were unable to make more frequent or extended use of the kits for student learning. Commonly, this limited longer-term planning, in that teachers found little space to introduce the kits into already "crowded" curricula or were unsure of where to position the kits within class's sequence of content. Teachers' comments here reflect the exploratory and introductory nature of much of the lesson activities. Furthermore, one teacher described how her colleagues did not think they would be able to incorporate the kits into their plans for the Term. This indicates that a lack of clarity around the kits' relevance for scope and sequence can affect uptake at a school level, and that some scepticism about the value of the kits for

student learning is perhaps an additional hurdle for implementing stem.T4L. For example:

- *Louisa, teacher: We've just sort of been trying it and seeing what we can do with it… They've been a little bit of my test dummies as well, to try and see what we have there… So I think, personally, I'd need to be doing more, [the] rest of the development myself to see how it can be applied and what we can do and how we can be using it in our curriculum…*
- *Marcus, teacher: With my year sevens, [we didn't use it] as many times because we had to get through a lot of the other content of the course.*
- *Cameron, teacher: We can't really do it in Maths… Everything's so crowded already. It'd be hard to make time for it in Maths.*
- *Olivia, teacher: I think with regards to other teachers, with the Google tours… I tried doing a little bit of training with them. That way they were able to see [the VR kits]. It didn't necessarily fit in with exactly what they were doing. And so some teachers were a little bit concerned with, like, 'is this just going to be like an entertainment piece for the students?' as opposed to really getting into what they really wanted to get into…*

Issues with preparation: professional learning, logistics, and time

In addition to programming student activities, teachers noted further issues that indicate limited preparation ahead of the arrival of the kits. These preparation issues have similarly influenced the degree to which teachers have incorporated the kits into their classrooms. The teachers often identified limitations in their own professional learning: rather than having time to prepare in advance, it is clear that a few teachers had to learn 'on-the-go' and that they only began to experience confidence or proficiency in using the kits until the later stages of the Term. For example:

- *Olivia: It was probably about two weeks also where it wasn't used by students where it was just me trying to learn how to use the kits…And it probably took me a while to then learn how to use each of the different programs as well.*
- *Louisa: One of the trickiest things … was me trying to figure out how to actually do it and what I need to do and how the setup is. And then having a play with it to try and figure out what you can do and what the capabilities of it are.*
- *John: Look, if it weren't in a selective High School environment – like I am here, where I can be a little bit lazy and let [students] take over because they're so smart – you really need to do the tutorials and try it out and have that time put aside it.*

Additional preparation issues occurred on a more logistical or technical level. In this area, the challenges of deploying the kits within a High School environment become apparent. Whereas the average primary school teacher will spend most of their day in the same classroom with the same students, High School teachers will obviously need to work on a period-by-period timetable. As one teacher noted, the challenge of setting-up equipment is accentuated when having to move around the school to a much greater extent than in a primary school setting. Other teachers described how, given the challenge of incorporating the kits into a regular coursework-based classroom, they had to utilise the PC Robotics kit in a final period Coding Club. Between setting-up and packing-up the kits, only a small amount of time was left for students to actually use the robotics equipment. The initial setup period is also when some teachers encountered technical 'teething problems', such as being unable to connect the kits to classroom displays or reset the kit from previous schools. For example:

- *Olivia: Because we didn't have a room set up where [the VR headsets] were, it became a bit of a process to get them from the location where they were stored and carry them…*
- *Natalie: Maybe the fact that it takes time to pack it up and pack it down as well, because we keep them in the staff room at night time… sometimes if I'm on class or I have duty before or after, I won't do it, just in case we go a little bit over and I don't have time to pack it up.*
- *Shannon: By the time they got started, they'd lost a bit of time already, then they had to pack away*

as well. And it was only once a week, so they'd lost a bit of focus on what they'd done the week before.

- *Marcus: And with that particular kit, the kit would not restart properly or it wouldn't shut down, or it wouldn't even do a hard shutdown to reboot. So with one particular kit, there was a lot of technical problems.*
- *Louisa: I think maybe knowing how to use it and how to set it up before we actually do it. So I had a bit of a look at it and was reading through the how-to guides and then when I went to set up, realized I was missing one of the emails that had the details for it…so that would be the first two weeks that we were using it, of trying to work out how to actually do it and physically set it up.*

Engaging and collaborating with other staff

Three teachers also described how they had struggled to engage their colleagues in using the kits throughout the school, or that they had encountered limited interest from other teachers. As discussed above, there were some preconceptions from teachers that the kits were less about student learning and more about "entertainment". There appears to be a general awareness of the arrival of kits at some schools and some fleeting curiosity from other teachers, but without substantial uptake beyond those teachers who had booked the kits themselves. Two of the teachers below posit some explanations, ranging from the absence of staff development days due to COVID-19 social distancing mandates. For example:

- *John: There is an English teacher who's got some interests because she's used the Google Cardboard in her classes in the past. But at this stage, she hasn't shown any real interest in coming over as yet.*
- *Louisa: …the main thing is particularly not being able to have staff development days, a lot of other staff haven't been aware to use it and because we can't all get together and show them how to use, it has been a little bit tricky…*
- *Olivia: …I tried to get all the staff members involved, so that way the kit was being used across the school in different subject areas… I think some of the biggest issues that other teachers found was the time associated with it and just their lack of confidence with regards to actually using the kit…That stopped a number of staff members from using it.*

Stem.T4L contributions to student learning

As explained above, the survey results did not indicate improvement in the target variables. However, the focus group interviews provided the chance to learn about what had been changed in the learning environment under the impact of the stem.T4L equipment. For those who had the opportunity to go further than an initial or cursory engagement with these technologies, the learning experience had improved significantly. Below we will discuss the main themes that emerged from the interview data, which shed light on the contributions of the stem.T4L kits to student learning.

Learning became tangible and concrete

Students and teachers alike reported that learning experiences had been improved due to the way the kits made learning more tangible or 'concrete' than in their traditional classroom experiences, in the sense that the objective of a learning activity became more tactile or visual. Importantly, these experiences were noted by students who had used all of the kits studied in this paper, whether 360° cameras, virtual reality headsets or robotic equipment. For example, in the school using the PC Robotics kit, both the students and their teacher noted the difference between learning coding and programming on a desktop, and doing so with robotics. As with the immersion of virtual reality, students noted that the kits have made learning more immediate or 'real'. Being able to visualise the logic and progression of an algorithm through the movements of a robot was reported as particularly helpful for some students' STEM learning. As one student articulated, this is particularly valuable given the diversity of learning styles that exist within a High School classroom. For example:

- *Tahlia, student: Well, the interactive learning [of the VR and cameras] helps – well, for me. Because I'm like a visual learner, it helps me more and it helps me understand the topic more.*
- *Maddison, student: The new perspective of, like, learning through interaction was a lot helpful for me because usually when I just sit down in a classroom, we would just listen. It doesn't really help me learn. But being able to like interact with something – that helped me a lot.*
- *Lakshmi, student: So it was good because we got to play a lot with our hands. Cos for that [previous] coding we did Python, and it was all on computer. …[then] we got to feel a lot with our fingers and then mostly just, like, play with Lego… I think it was more interesting because of it. Because we got to connect it to the PC. When we did it, we got to move into a lot of actions that I found more interesting – cause we actually got to visibly see a figure [the robot], and have it progressed.*
- *Shannon, teacher: They saw the connection between the coding and using the coding to make something move. Normally when they do coding, it's just on a computer, they don't see the impact of that. So, I guess the [stem.T4L] kits allow them to see the practical aspect of coding… the potential of it.*

STEM learning was easier and more enjoyable

Some students reported that using the kits had made STEM learning easier, while others reported that approaching challenging content was more enjoyable because of the kits. Students also reported improvements in their content knowledge for particular subjects – such as understanding cells in a biology unit, following a virtual reality tour into the microscopic components of the human body. There is also data (from teachers and students) suggesting that the kits have aided students' ability to recall content explored in class, such as in exam conditions. Examples include:

- *Christina, student: You get a better understanding of the topic. And you just get to learn lots from just being there and the teacher guiding you along that journey in school.*
- *Li, student: It felt like we were there, because with the VR you could look around and stuff. So we could see more of the cells.*
- *Charlotte, student: I definitely remembered things from doing the VRs, like in cells, so I've*

learned a lot. And then when Miss asks us a question, I'm just like, "Oh, I remember that from the VR."

- *Hannah, student: Even the kids that weren't interested in the topic liked the topic when they were using the VR kits.*

- *Marcus, teacher: I think with my year 12 IPT class, they do a multimedia unit and I've noticed that they are now able to answer questions more confidently. And they've got more to say if the question was related to virtual reality systems...*

Students also reported improvements in relation to refining architectural designs, producing media content and learning foundational concepts in coding and programming. Skills in using and manipulating technology itself were also improved, and teachers often noted how their students were the 'experts' or drivers of change in the classroom.

- *Ruby, student: I liked [STEM] all along, but I feel like after having this experience I understand it more. So now I like it even more because I know more aspects of it.*

- *Tahlia, student: Everybody paid attention to detail more. And they learned a lot more from the VR kits.*

- *Olivia, teacher: Two girls in year 9, when they were making their energy efficient home, you could actually see that they didn't realise how easy coding was. That was really good to see. And they were actually saying that they were really into it and they really liked it, and I think they were amazed at their own ability of being able to do something like that. As if they had pegged themselves as not being able to do something...*

Opportunities for self-directed learning

The kits also presented students with recurring opportunities for self-directed learning. A small proportion of students described how using the 360° cameras was beneficial for autonomous and exploratory learning. There is a clear sense of freedom in the responses below, both in terms of the freedom to choose and in relation to mobility – being able to take STEM learning outside the classroom, and see where it leads. One teacher corroborated this view, also in relation to activities that used the 360° cameras as a component in project-based VR learning. However, some teachers using the PC Robotics kit described experiences of self-directed learning in a more anticipatory sense; that while this pedagogy had clear potential, their students were at present too unfamiliar with it. In these teachers' views, more substantial gains in student learning could be realised, so long as their own teaching styles and lesson structures were revised accordingly.

- *Zahra, student: We got the chance to do things a bit on our own a bit kind of like figuring out how to use tripods properly and all the cameras properly and connecting them to our phones, and it made it more hands-on and enjoyable.*

- *Marcus, teacher: Once I had set them up with it, they were able to just go on, navigate and it was very much just an open world for them to explore. I didn't set any specifics in their use of the kits. So I think they enjoyed that ability to be able to roam around and explore at their own will.*

- *Olivia, teacher: It was interesting because I just wanted to show them the real basics and then they took themselves from there. There was no real need ... for me to be fully conversant in the use of it. I knew how to use the tour. I obviously had to know how to use that one and get them all connected on the phones. But in terms of any of the other stuff, like the cameras, I quickly showed them and then off they went and they found out their own things...*

- *Cameron, teacher: They're not used to being self-directed. They're not used to, say, having to find their own solutions or even asking for help if they get stuck. They might be a bit reluctant, thinking the answer should be obvious or they should know what to do when they're in a situation where they are a bit more free, and they do have to come up with the solution themselves. So that was one big impact, I guess, yeah. Realising to teach a bit more in that way and structure situations like that, so they do develop those skills.*

Reappraisal of STEM career and study pathways

As we discussed above, no change in student STEM career aspirations was observed in the surveys. However, the qualitative data based on the focus group interviews was mixed on this point. On the one hand, a large proportion of students were ambivalent about the effect of the kits on their future career or study choices, with several noting that the kits had not changed their views about STEM, which was consistent with the survey data. For example, when asked if using the stem.T4L kits changed their perception of STEM careers or study pathways, students at one school using the VR kits replied by saying, "No, not really," and "Yeah, kind of. Maybe." This would imply that using the kit has had little impact in this regard.

On the other hand, select students reported that the kits had exposed them to STEM fields in greater depth, and that this has already altered their perceptions about what it would be like working in a STEM career. Again, careers in videogame development appear to be motivating factors for some students' engagement with virtual reality, while using the PC Robotics kit helped one student reappraise careers in programming. While this question was only asked of students, some teachers also commented on the positive impact of the kits for helping students make decisions about their futures in work and study. Examples include:

- *An, student: It was just cool to like be in the moment I guess and kind of experiencing what STEM creators might be and people in STEM can do. Like, we got to experience that as well.*

- *Maddison, student: Honestly, yes. After using the kit. Cause originally I was never really interested in STEM but after joining the Coding Club and then being able to experience just trial and error with this kit and hands on the experiment as well, it became enjoyable. So then I get to learn about Technology, Science and apply what I knew to what I was learning.*

- *Lakshmi, student: I was really on the fence with picking a job in the future towards I.T and Programming. With the robotics, I was able to get to know more about that type of field. And so it made me more interested in like picking a job in it.*

- *Chloe, student: I guess it just gives me a lot more respect towards people in the STEM field, because realistically this kit was more towards the beginner side because of the coding and everything was pretty straightforward. So the people that actually code through harder languages and they're like really cool. It gave me a lot of respect for them.*

- *Marcus, teacher: I think it also just gives them... If they thought about career options, it gives them an idea of further interests in career paths that they may like to pursue going forward, post-school.*

Teachers and students gained insights and learned lessons through their one-term journey with the stem.T4L kits, and these were of key significance to research and are important for the future direction of the project. We concluded our interviews with a discussion on the main challenges each group of participants faced, their suggestions for the stem.T4L project team, and their advice for other teachers. We elaborated on teachers' barriers to implementation of the kits above. In the following section, we will report on students' main challenges and each group's ideas for best practice.

Challenges faced by students

Students discussed a range of negative experiences that impacted their use of the kits; however, most of these appear easily surmountable. Students using the VR kits often reported some physiological or sensory issues due to their unfamiliarity with virtual reality. Other students noted some drawbacks that became evident during specific kit-based activities. For example, although coding using robotics may have been interesting for most students using the PC Robotics kit, several did not find block coding to be an adequate challenge for their skill-level. Students also encountered some administrative or logistical barriers to using the kits, such as not having appropriate licenses organised for particular apps.

The unfamiliarity of new sensory experiences

Numerous researchers have noted 'cybersickness' as a common side effect of using virtual reality (Davis, Nesbitt & Nalivaiko 2014; Gallagher & Ferré 2018). The discrepancy between a user's motion and the visual stimuli they receive from a VR headset can lead to symptoms of motion sickness. Some mild 'cybersickness' was reported by several students who had been using the IVR kits, as were other physiological or sensory limitations – feelings of disorientation and reduced hand-eye co-ordination, for example. For example:

- *Arjun, student: Yeah, some people get motion sickness from using it...[And] Hand-eye coordination. So you don't really see your hand, you see your players hand.*
- *Tom, student: In the rollercoaster one, there was a big jump in one part, and every time it jumped, the person using it always stumbled backwards, or started getting a bit stiff.*
- *Tilly, student: You don't know which direction you're facing.*
- *Ella, student: You feel kind of dizzy after.*
- *Tim, student: Like, getting used to the feeling of being in the VR [is a challenge], at first. Cause you don't see your surroundings as it is. You just have to picture that you're not going to fall over anything...*

The students in this study appear to have been comfortable with a period of acclimatisation and describe how these experiences were more prominent in earlier lessons with VR. For any teachers who encounter these issues in future, the stem.T4L project provides numerous resources to prepare teachers for this: an online video that introduces students and teachers to these new sensory[2] experiences, a Risk Management Plan that helps teachers provide a safe operating environment for IVR[3], and a permission note that allows schools to obtain parental consent (for students with particular medical diagnoses or communication difficulties, for example).[4]

Activity-based limitations

Several students pointed to drawbacks or hurdles that they encountered during specific kit-based activities. For the students who used 360⁰ cameras, some reported issues with using the camera tripods and others noted the occasional difficulty in capturing high quality images for their VR tours. For those using the PC Robotics kit, some found that the block coding that accompanies Lego EV3 exercises was too simplistic for their skill level (owing in part to previous block coding exercises undertaken before the kits' arrival). A handful of students reported experiences of disengagement due to this drawback – while they remained in their school's Coding Club, they decided to return to learning other programming languages using laptops or desktops. Finally, students using VR headsets noted that not enough headsets were available for all the class to use, which limited their ability to spend significant time in virtual reality environments (there are some intractable budget and logistical considerations here, which are discussed further under 'Suggestions').

2 The video is accessible on YouTube, via this link.
3 The Risk Management Plan is accessible on Sharepoint (using a DoE login), via this link
4 The draft permission note is accessible on Sharepoint (using a Doe login), via this link.

- *Ethan, student: With our camera we've had difficulties with the weather and things. So we had a camera issue when we put the camera on the tripod and it was a not very nice day for it and it just blew the camera straight over so that wasn't too good.*
- *Georgia, student: When you take the photo, you can still kind of see the tripod under it when you put it in the virtual reality...So having that still there in virtual reality for people to see, they'd be like, "Why is there just a random tripod there?"*
- *Zahra, student: Depending on what, where you position your phone, if your phone's too far away, the camera doesn't come out good quality and it's very blurry and sometimes you just get black dots on...*
- *Chloe, student: We already had experience with the kit. So then also like I'm using it this time during Coding Club, because like the coding aspect was more like towards like blocks and it was a bit simple, so that's why we decided to transition to other programs about Python and other...*
- *Ava, student: We already did it in IST [Information and Software Technology] before so it was fun the first time, but the second time around was a bit boring.*

Participants' suggestions for best practice: getting the most out of the stem.T4L kits

Teachers were also asked to provide advice for fellow teachers, based on their experiences with the kits thus far. A host of valuable advice was offered, in the form of practical suggestions for getting the most out of a kit booking and offering encouragement on a more psychological or emotional level. In terms of stem.T4L, an array of practical suggestions were proposed by students and teachers, ranging from some modifications to project delivery, suggestions for refining learning activities for the kits, and improvements to the equipment within the kits.

Teacher and student suggestions for stem.T4L

Teacher and student suggestions for improving or refining the stem.T4L project most commonly involved technical or logistical considerations, ideas for how the teaching and learning experience could be improved, and some additions or changes to how the project is delivered to schools. In terms of technical considerations, students and teachers noted that additional headsets would be a valuable inclusion for both of the virtual reality kits. Acting on this feedback is perhaps unfeasible, given that there would be significant costs in doing so (and related concerns around securing and maintaining the equipment), albeit more so with the immersive VR headsets.

Interestingly, no technical improvements were suggested with the PC Robotics kit or the 360⁰ cameras. In addition to the above consideration, one student also identified that wireless headsets would be a valuable addition to the IVR kit, while another believed that the accuracy or fidelity of the IVR controllers could be improved upon. Further to the challenges that students encountered with the unfamiliar sensory environment of the VR headsets, one student noted that the opportunity for involving additional media content in virtual reality would also be beneficial – such as adding audio to VR tours, thus making the IVR kit a more multi-modal experience. Further examples include:

- *An, student: Yes, having multiple [headsets] able to use at once.*
- *Tim, student: [The VR headset] has a cable which needs to be attached to the main computer, so making that wireless would help with this. Some people were very close to tripping... Because, when you're in it, you don't know your actual reality.*
- *Mackenzie, student: ...have more senses in it, rather than just covering your eyes... having the opportunity to use our other senses during a game.*
- *Marcus, teacher: Teachers are identifying as well as the fact that we only had the 10 headsets.*

For teachers when they've got 30 kids in a class, that does make it a little bit more challenging, particularly if you are doing the Google tours.

Regarding teaching and learning modifications, the more common response from students was that better integration across faculties or KLAs was needed. This could, of course, be considered as a limitation in teacher preparation: that it is their responsibility to program lessons so that kits are incorporated into the classroom more broadly. However, one teacher made a valuable suggestion for stem.T4L in this regard, that providing teachers with an easy to access "checklist" that linked VR apps to particular KLAs would assist this lesson planning. In addition to these considerations, students using the PC Robotics kit pointed to the value of including additional programming languages in these activities, or at least the introduction of scalable challenges within each activity (again, this could be put back on the teacher). For example:

- *Arjun, student: Using it in more subjects… because you'd be able to learn more stuff. Such as geography, you'd be able to visit the places you're learning about.*
- *Tim, student: Currently, only TAS uses these things…we only use [them] in graphics… if science and maybe maths…and maybe social science, had these kits to teach us with, then we could learn more [with] other faculties as well, not just this.*
- *Maya, student: Maybe doing like a conjoined kind of learning lesson where multiple people can join like a VR session and then be in the same kind of thing…and with that we can all interact with each other and tell each other what we're seeing and each other, we'll be able to understand.*
- *Ava, student: Just more variety in like the creating aspect, the coding was really, like, simple. It was using blocks and all that. So maybe those little options or there are just bigger variety.*
- *Marcus, teacher: There might need to be more, maybe suggested apps for certain classes… Because it is a time consuming process to download and install a bunch of apps, and then it's time consuming to go into each individual app. So maybe kind of a suggested checklist of apps per subject would be useful to say, for example, "Use Google VR in a geography class."*

Teachers' advice for other teachers

Teachers were generous in their advice for other teachers who might be approaching using the kits for the first time. In practical terms, one prominent suggestion was to find a dedicated location in one's school, so that the kit (particularly immersive VR) can be housed for the duration of the term without the need to pack-up and setup for every class. Seeking team teaching opportunities or collegial advice was also suggested, as was taking the time to see a stem.T4L Leader model how the kit can be used. As per the challenges identified in ensuring adequate preparation, teachers also emphasised the need to spend time with the stem.T4L resources that explain how to setup and use the equipment. Examples include:

- *Louisa, teacher: I think talk to teachers that are doing it. So I think it's been really good that there's me and another teacher that are currently doing it at the moment. And just even bouncing off each other, she was like, "Oh, this is what we did in class." I was like, "Oh, that's really cool. How could we use that sort of thing?".*
- *Natalie, teacher: I guess giving [students] ground rules to start with, and then making sure we're set up and ready to go, and everything and the technology is working.*
- *Marcus, teacher: Definitely go through the learning guides. Keep a copy. I have a copy on my phone, other teachers might prefer a hard copy. And have the contacts for the tech support if issues arise. But then also, maybe if they want to use it for a specific subject area, then have a look at the apps that you want to use with the VR as well…*
- *John, teacher: Look, for this you do need a space that's available.*
- *Cameron, teacher: I'd say just first off, just get as much knowledge about the stuff as you can yourself, even just playing with it and doing online courses or whatever and seeing what's available.*

- *Shannon, teacher: I would say, play with the kits yourself and become familiar with them… Or get some advice from more experienced teachers…*
- *Olivia, teacher: If there's a classroom that's set up like… a STEM lab or something like that, where the equipment's located and is able to be stored securely, and that way the teacher in the class moves to the equipment as opposed to having to transport the equipment all around the school.*

Three teachers also offered more emotional or psychological advice that encouraged teachers to overcome any preconceptions or fears of using new educational technology. Two teachers who used the IVR kit argued that the enjoyment that students derived from the kits was worth the investment of a teachers' time and effort – and that making this investment was not particularly arduous or confronting. One teacher also implored new users to take the time to understand the pedagogical affordances of virtual reality, and that this would deliver benefits in terms of implementing the kit. For example:

- *Natalie, teacher: Give it a go. I feel like the kids know a lot more than we think they know as well, so they can always help out. Even getting it into our programs has been really good. It's really engaging for the kids.*
- *John, teacher: Don't be afraid of using the technology. It's really not that hard. It's just like learning anything new. Once you used it a couple of times, it's quite simple and straightforward, but there is a little bit of a learning curve just like using CAD software.*
- *Olivia, teacher: They need to understand the importance of it and appreciate the value in it… And if they can appreciate the value that it does bring, then they're probably going to be slightly more inclined and motivated to actually learn how to do it, or at least spend that little bit of extra time doing it.*

CONCLUSION AND RECOMMENDATIONS

The interplay between learning experiences created by the stem.T4L educational technologies and High School students' reappraisal of STEM in terms of changes in their attitudes, interests, confidence, and future career aspirations, was at the crux of this study. We collected detailed quantitative data through pre and post surveys (N= 185), and qualitative data through focus group interviews with students and teachers from six High Schools (40 students & seven teachers). As they reflected on their one term experience with their stem.T4L kit, students who took the post survey reported a satisfaction rate of 71%, indicating the project had attained notable success in delivering positive experiences. Some researchers maintain that students opt out of STEM subjects based on experiences, and sometimes even a "single" experience is enough to dissuade them from a course of study (Egenrieder, 2010). Others also propose that there is a strong link between experiences gained in STEM classes and persistence in STEM (e.g. Cleaves, 2005). Given students' favourable impression and evaluation of their one term journey with the stem. T4L kits, we expected a significant difference in the mean scores of the variables under study (i.e. STEM interest, self-confidence, attitudes, and future career aspirations). However, the statistical analysis suggested no discernible impact on the variables, with all ratings remaining unchanged from pre to post evaluations.

Despite the lack of improvement in these variables, significant findings emerged from the data that directly pointed to the achievements the stem.T4L project had gained on a few fronts and the favourable impression it had made on students.

These key findings are summarised below and their implications are discussed:

1. When asked about the competencies that students perceived had been improved as they worked with their kit, 89% were able to identify improvements in one or more competency. Creativity and collaboration were chosen by the majority of students, regardless of the kit they used. Research on educational technologies offers corroborating evidence where development in student teamwork, creativity, and problem-solving skills in technology-integrated instructions are frequently observed (Tyler-Wood et al., 2018). Based on the findings of our mixed-methods study, we argue creativity and teamwork are the two main corresponding skills that students feel more confident in as they get the chance to work with stem.T4L equipment. The focus group interviews also supported the idea that stem.T4L technology-integrated instruction established a collaborative environment where students reported a greater sense of teamwork and collective engagement with activities, which they had not experienced through other lesson plans and structures.
2. Filtering the data based on the type of kit yielded interesting results; we found that those students that used HVR (27%) and IVR (25%) rated their creativity higher, compared to other groups with a different kit. Meanwhile, students with 360° Cameras (34%) and PC Robotics (31%) claimed that they performed better in collaborative work. Suggesting the existence of a definite link between kits types and certain competencies requires detailed correlational studies. However, the data collected through this research hints at some potential association between each kit and the skills they cultivate. Teachers are recommended to take into account these findings if they intend to encourage certain capabilities through stem.T4L kits.
3. The focus group interviews shed further light on the contributions of the stem. T4L equipment in terms of classroom engagement and student learning. Students and teachers alike discussed the autonomous and exploratory learning that use of the equipment had encouraged. The stem.T4L technologies had also created tangible and concrete classroom experiences leading to a more solid grasp of learning concepts, especially in STEM. Teachers also noted proudly that their students had improved their ability in coding and programming and developed skills in using technology as they worked with the stem.T4L kits. A heightened level of engagement was another distinctive feature that students and teachers had noticed and felt in the classroom when they were exposed to the technologies.

Based on the findings of our research, we conclude that the incorporation of the stem.T4L technologies enhanced students' learning experiences; however, there were other factors at play that limited the extent of its impact. In their research on the effects of technology in classrooms, Falck, Mang and Woessmann (2015) found that three factors lessened the effectiveness of technology, including student background knowledge, student social class, and teacher competency levels with the technology. Looking at the present data, we observed that 11% of students believed they had not developed any skills through this experience and 22% took a 'Neutral' position when evaluating their experience with the stem.T4L kits. Although students' intrinsic motivation and their prior experiences might have played a part in their evaluation of the project (factors beyond the focus of this study), there was some evidence that suggested some students had limited opportunities for using the kits. Comments such as we "started in the last few weeks", and "did not learn much" or "did not get to use it much" signalled the sporadic usage of the kits. Also, as discussed above, focus group teachers revealed that they faced several challenges that had limited the integration of the equipment.

These observations highlighted a few areas that we argue contributed to the observed lack of improvement in the variables under study. These factors include: (1) teachers' lack of substantial investment in planning and designing relevant learning activities; (2), already crowded lesson schedules; (3), lack of collaborative exercises or interest at a whole-of-school level; and consequently (4) limited opportunities for students to use the technologies. Most of the data that leads to these conclusions was drawn from teachers' interviews from six schools, however, when contacting schools to recruit focus group participants, others outlined similar underlying reasons (e.g. being too busy, having exams, kit being used by another teacher) for their infrequent use of the kits, and hence their unwillingness to participate in the research. As such, the present findings might be relatively generalizable to other High Schools that used the stem.T4L kits in Term 3.

This research has important practical implications for teachers and the stem.T4L project group, which we discuss below.

1. Teachers are the backbone of any classroom initiative, and for new technology to be effectively integrated into lessons, teachers should be provided with time and opportunities to explore the technology, familiarise themselves with its potential and design activities and learning outcomes that best develop students' skills and ignite their interest. The stem.T4L project offers online and face-to-face professional learning and provides resources and how-to-videos to maximise the effectiveness of kits' usage. Although many teachers have tremendously benefited from these opportunities in the past (as previous research on this project suggest), there are still teachers who struggle to find time to make use of the available resources. Prolonging the intervention by offering the stem.T4L equipment for two consecutive terms, which in some occasions has already occurred in a few schools, will provide a more extensive exploratory stage for teachers whereby they invest in preparation, planning and upskilling. Alternatively, teachers could even be directed to complete a 'Before you receive the kit' questionnaire before they are able to make a kit booking. For example, they could be asked, 'does your school have an available space for setting up the IVR kit for a term's duration?' Questions such as these would prompt teachers to consider the practicalities of using the kits, before finalising their request to have one.
2. Designing lesson plans and learning activities that do justice to the affordances of stem.T4L technologies, and learning objectives aligned with the developmental stages of learning, are crucial to an effective implementation. If the activities and expectations set and introduced are not within students' Zone of Proximal Development (Vygotsky, 1978), students might find the technology-led instructions "underwhelming" or "boring", as some students expressed in the post-survey. An immediate impact of lesson activities not suitably adjusted to students' developmental level is feeling unchallenged to build on already established learning or failing to develop new skills. What we recommend is

teachers orchestrating and sequencing learning activities that are stimulating, well-planned and developmentally appropriate. Project-based learning (PBL) approaches, which a few of our participating teachers stated they had implemented in their classrooms, are one of the most frequently used and effective pedagogical methods to integrate new learning technologies. Grounded in problem-solving exercises (Krajcik et al., 1998), PBL engages students in a learning process that yields meaningful learning experiences for them. As Colley argues, the components of PBL include: "1) a rich, complex driving question that is relevant to students' lives, 2) production of artefacts, 3) student-centred learning, 4) collaboration, 5) accountability, 6) authentic use of technology, 7) interdisciplinary and cross-disciplinary inquiry..." (2008, p.25). When students use learning technologies as a tool to investigate the world around them and to solve real-world issues that are relevant to them, the learning process becomes more active and engaging (Maltese & Tai, 2011; Rivet & Krajcik, 2007) and this can ultimately foster positive attitudes and spark interest. As per the point above, the stem.T4L Learning Library contains resources to this end – a series of Learning Challenges that can be filtered by kit, age group and KLA, and that teachers can either implement directly or tailor for their own unique needs.

3. In some schools, stem.T4L equipment served as a tool for entertainment – something that provided a break from routine activities but had limited relevance to school life. It is likely that the short life of this 'trial-before-purchase' experience (i.e. one school term), which might not necessary lead to the purchase of these technologies by schools because of schools' limited budget and the costs of such learning technologies, had hindered teachers in their efforts to allocate more time and energy to integrate the kits in their classrooms. Yet developing an understanding that technology-enhanced learning prepares students for future careers is something that starts within classrooms (Spires, Lee, Turner & Johnson, 2008). Students need to appreciate and recognise the value of STEM learning technologies, and understand how they help to produce learners who are problem-solvers and can think critically and work collaboratively – the skills that are in demand in tomorrow' technological world (World Economic Forum, 2016). As the teachers in our study acknowledged, stem.T4L offers learning experiences that many students might not have otherwise. As such, even if it is a short-lived experience, it can act as a springboard to a heightened awareness and familiarisation with STEM skills, possibilities, and careers. We encourage teachers to have classroom discussions that explicitly frame stem.T4L activities in terms of the significance of learning new technologies, the skills and competencies they cultivate, and the future careers and opportunities waiting for people armed with those skills.

4. As Boyd (2017) puts it, the structure of High Schools encourages teachers to remain in their teaching disciplinary silos, which highlights absence of close collaboration between teachers in High Schools. This was observed in our data where teachers talked about lack of collaborative exercises, as a hindrance for greater uptake of stem.T4L equipment across school. Apart from proper considerations given to lesson planning, setting learning objectives and participating in professional learning, teacher collaboration needs to be in place for new learning technology to be integrated. Supportive school administrators play a pivotal role in facilitating regular opportunities for teachers to meet and collaboratively discuss technology-led procedures and instructions. Research shows that collaboration structure greatly affects the success of interdisciplinary STEM practices (Wang, Charoenmuang, Knobloch & Tormoehlen, 2020). We recommend that teachers participate in three reflective cycles phased in on arrival of their stem.T4L kits, halfway through their journey, and at the end of the term, to discuss possibilities, share ideas, and seek or offer technical and pedagogical support. A support system as such generates a sustained and widespread interest amongst teachers to systematically and consistently integrate the new learning technologies and produce outstanding results.

Changes in student STEM perceptions, confidence and interest take place slowly over time, as they directly experience and appreciate the world of possibilities that STEM education opens to them – particularly when these experiences are powered by STEM learning technologies. However, based on the findings of this research, we argue that it is only through a sustained integration of STEM technologies – when teacher enthusiasm and willingness *manifests* in preparation and time allocation – that we can expect noticeable results in High Schools.

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