stem.T4L

Term 4, 2018 report on the stem.T4L Project

Observations and insights from the research on the contribution of a state wide STEM project.

This paper presents results of an empirical study conducted on primary students and teachers involved in the stem.T4L project in Term 4, 2018. The report looks more closely at the changes in participants' STEM self-efficacy, attitude and interest over the course of the study.

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The stem.T4L Project was formerly known as STEMShare Community

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1. EXECUTIVE SUMMARY

A preliminary report was released in December 2018 on the pilot phase of the STEMShare Community Project, a longitudinal project that spans over three years, indicating that it has scored notable success. Surveys and focus group interviews were used to collect data from the 37 schools that had booked a kit in Term 3. In total, 44 teachers, 446 primary and 29 secondary students filled out the online surveys administered through Qualtrics and three groups of teachers in three different schools participated in the focus group interviews.

The data suggested that 68% of teachers implementing STEMShare Community equipment were promoters of the project and 86% were satisfied with the professional learning they received. The two main sources of satisfaction for teachers were the adequate and quality resources they received and the considerable support from STEMShare Community Leaders. In addition, teachers repeatedly emphasised the contributions of the STEMShare Community equipment to student engagement and pointed out that the kits offered a state-of the-art way of learning and improved students' teamwork and social skills. High level of satisfaction with and appreciation for the STEMShare equipment was found among primary and secondary students, with 84.55% of primary students agreeing that they enjoyed working with the kits. Positive emotions such as being happy, excited, in control, and entertained frequently emerged from the narratives produced by primary students.

The research findings gained from the pilot study contributed to the enhancement of the project that rolled out in Term 4. The present report provides an overview of the extensive set of data gathered in Term 4 from 255 schools that participated in the second phase of the research. The substantial volume of the data, especially the data collected from primary students, diversity, and vigour of the views expressed by teachers made for a very interesting data set. In total, 245 teachers and 1483 primary students completed the pre and post surveys administered at the beginning and end of Term 4. Although a specific survey was designed and administered to secondary students, the relatively low number of responses gathered from this cohort did not produce reliable data and hence the analysis was excluded from this report. The thorough examination of the findings revealed that the STEMShare Community project benefited the participating schools in the following ways:

- Improved teachers' attitudes towards STEM education and significantly advanced their STEM self-efficacy beliefs.
- Created a community of practice through establishing an online forum (e.g. Twitter, YouTube, and Yammer) for teachers to collaborate and share their experiences.
- Increased student engagement as agreed by the majority of teachers.
- Enhanced teachers' knowledge and expertise of STEM teaching and learning.
- Developed students' 21st century skills including creativity, teamwork, and communication.
- Specifically, enhanced girls' STEM-self efficacy and boys' STEM attitudes.

The project created an absolutely positive impact on the two groups of respondents, however, there were relatively few dissenting voices from the teacher cohort that is worth noting. The ratings and commentaries highlighted that some teachers were critical of the STEMShare Leaders on the grounds that they had not received any training. This was attributed to the low ratio between STEMShare Leaders (N=10) and schools having a kit in Term 4 (N=526), which was almost one to 52. However, the schools that did receive one-on-one training from leaders confirmed their substantial contributions.

2. INTRODUCTION

One of the factors that determines who remains and who leaves STEM is the type of educational experiences students have in their STEM classes (Cleaves, 2005; Munro & Elsom, 2000). In other words, implementing effective pedagogical practices and establishing learning environments that stimulate student interest in STEM majors can enhance their attitudes to STEM, increase their interest, improve 21st century skills, and influence their intent to pursue STEM majors (Cleaves, 2005; McDonald, 2016; Tai, Liu, Maltese, & Fan, 2006; Wang, 2013; Wang & Staver, 2001). To this end, STEMShare Community Project, as a state-wide STEM initiative, intends to generate STEM interest through introducing state-of-the-art STEM equipment into NSW K-12 schools to ultimately maximize student likelihood of pursuing STEM subjects. The present paper investigates the effectiveness of the STEMShare Community project in Term 4 by comparing the baseline findings, gathered at the beginning of Term 4, with the follow-up outcomes, collected at the end of Term 4 to measure the differences made in the variables under investigation over this ten-week period. This research implemented a pre-test-post-test design drawing upon survey methods to collect data. As Shaha, Lewis, O'Donnell, and Brown (2004) asserted, ''Pre-test and post-test designs add the capability to assess change or improvement (immediate and continuous), as well as the ability to adjust for pre-existing differences. Improvement, or change from pre-test to post-test occasions, is increasingly being seen as a primary and fundamental measure of program success'' (p. 4). Hence, two surveys were designed and administered through Qualtrics to two stakeholder groups: primary students (Year 4-6) and teachers in Term 4 before and after the participants used the STEMShare Community equipment. The following research questions guided the investigation and analysis of the data:

1. To what extent did teachers' and students' STEM self-efficacy, interest and attitudes change from baseline to follow-up?
2. Was there any statistically significant difference between girls' and boys' mean scores for the measured variables?
3. To what extent was the STEMShare professional learning effective in upskilling teachers' STEM teaching and learning?

The analysis conducted on the surveys and the findings are presented below.

3. TEACHER SURVEY

The Teacher Surveys administered at the beginning and end of Term 4 included almost identical items and measured three variables (i.e. STEM Attitude, Interest, and Self-efficacy beliefs) using a five-point Likert scale format (1 = strongly disagree to 5 = strongly agree). Teachers were also prompted to provide comments on the questions if they wished to do so. In addition, teachers' views on the challenges of integrating STEM education were explored through open-ended questions in both pre and post surveys. The commentaries collected from teachers were read again and again and categorized into themes as part of the content analysis, which further contributed to the interpretation of the data. The post-survey included an additional section on the effectiveness of the professional learning, as will be explained below. 517 teachers (418 female & 99 male) participated in the pre-survey of whom only 245 (192 female & 53 male) completed the post-survey. It is worth noting that we received a total of 352 responses at the end of Term 4, however, to measure the extent of improvement from pre to post implementation, the research population had to be exactly the same. Hence, the respondents who had not taken the pre-survey were excluded from the analysis. To analyse the pre and post data, initially, the mean score of each item was measured through Qualtrics by assigning 5 points for a response of "strongly agree" down to 1 point for a response of "strongly disagree". In other words, higher scores were associated with higher STEM self-efficacy beliefs, more positive attitudes towards STEM, and greater STEM interest. As Table 1 shows there was a positive shift in the mean scores of all items from pre to post surveys.

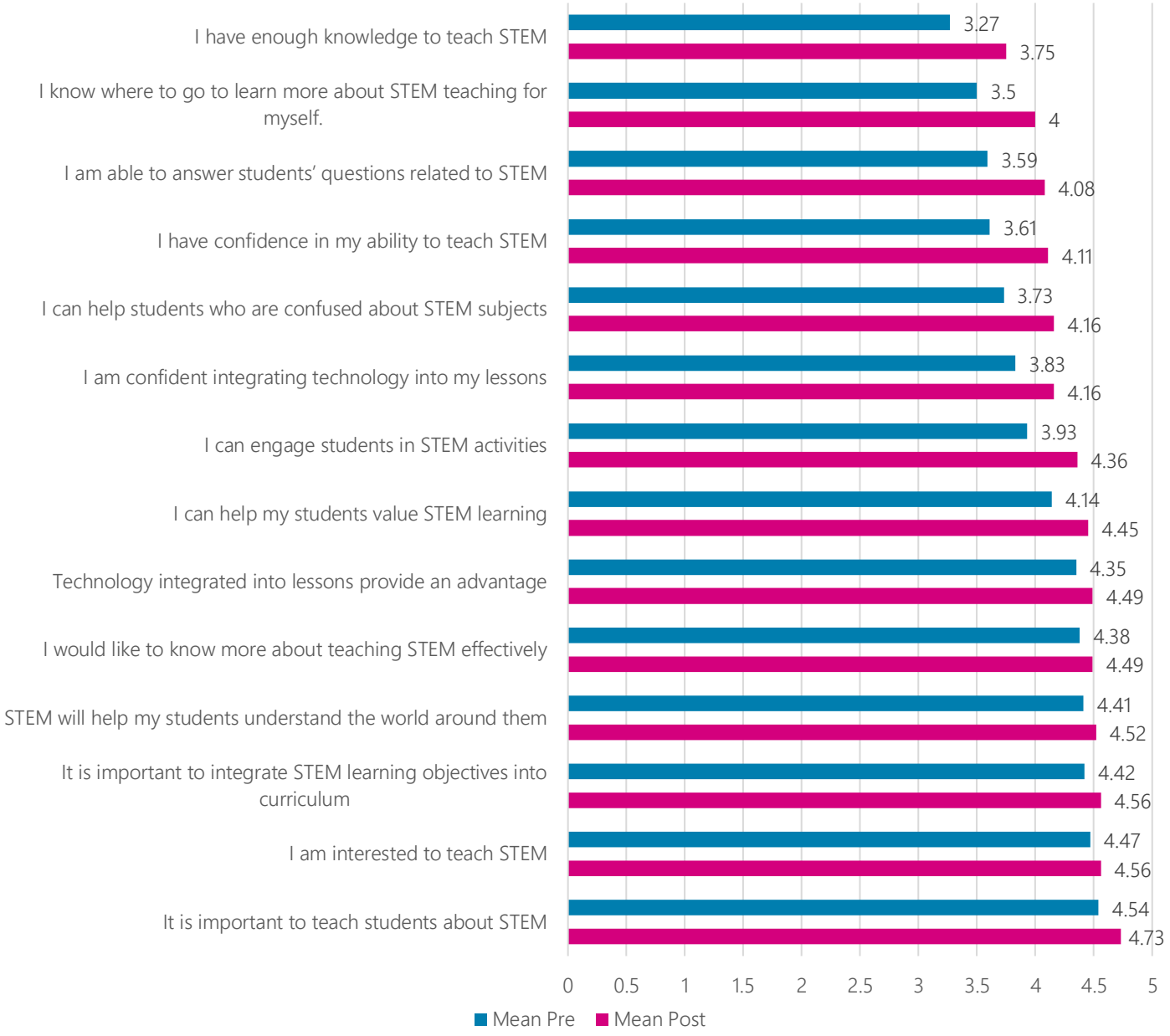


Table 1. Mean scores in pre and post surveys by item

Given the notable rise in the mean of each item from pre to post evaluation, it was expected to observe an increase in the overall mean score of the post-survey and, as depicted below, an increase by 4% was found.

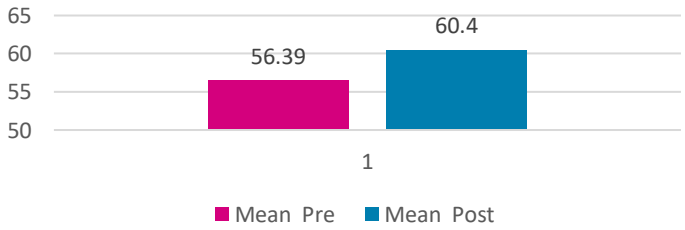


Table 2. Total mean scores in pre and post survey

3.1. CHANGES IN MEAN SCORES OF VARIABLES UNDER CONSIDERATION: STEM ATTITUDE, INTEREST, AND SELF-EFFICACY

After categorizing the items based on the variables they intended to measure, it was revealed that teachers rated the items of variable 1 (Attitude) and variable 2 (Interest) consistently high at the pre-test, with all the items falling between "agree" and "strongly agree". In other words, overall, teachers had a keen interest in teaching STEM and a favourable attitude towards STEM integration and its benefits at the outset of Term 4. The commentaries provided by teachers provided support for this argument. As teachers set out on STEMShare journey, they expressed extreme eagerness and enthusiasm to "gain quality skills", "upgrade [their] knowledge", learn "best ways to teach", and "integrate STEM in a meaningful way". Some highlighted their lack of expertise in teaching STEM, however, they were equally keen to participate in any workshops to upskill themselves and expand their STEM capabilities:

- *For me, I just need to do it now. I'm ready to inspire and engage the kids in realistic learning that will help them in their future.*
- *I'm very keen*
- *Only inhibited by the costs of PL. I think a lot of teachers would like to learn more.*
- *I would like to know how to integrate it into our science units as a 40 min RFF*
- *I would like to know where it is most effective and how to integrate it further.*

I would be interested to learn more about teaching STEM subjects as I haven't had much experience teaching them yet in my career. I would like to explore lots of different areas to build my confidence in all aspects of STEM education.

- *I am in the beginning stages of teaching STEM and am keen to investigate and develop my skills in this area.*
- *I am the Principal and am looking to implement ideas across the whole school.*

I feel that STEM is new to my teaching and would like to gain quality skills and knowledge over a period of time to engage and develop skills for my students to enjoy, but most of all be significant to their learning.

- *I currently incorporate STEM into many KLA's however I would like to be more efficient at doing this and often need new ideas.*
- *I'm interested in learning more*
- *Would participate in any STEM Workshops*
- *I am keen to teach STEM as I can see the great advantages that it gives to the students.*
- *I am eager to learn, but not confident in my own ability to teach STEM. I use technology a lot in my classroom and my students know that I am keen to teach them about technology and STEM*
- *I am interested in attending hands on workshops demonstrating how robotics, programming and coding can be used in the ES1/Stage 1 classroom to teach STEM.*
- *I am always happy to upgrade my knowledge.*
- *I am really eager to implement into all areas of teaching and tying in with project based learning.*
- *I feel I can always improve my teaching to be more effective and support those students who need more.*
- *Although I have a great deal of background knowledge I feel there is always more that I can learn. Attending ICT days, watching STEMShare videos, reviewing blogs and the journey of other teachers are beneficial. We have a colleague who is completing a STEM Teaching scholarship and professional dialogue with her is informative and beneficial. Experiencing STEM activities and providing opportunities to students is motivating and supporting my knowledge and experience.*

STEM is amazing to teach and the students gain real world value and hands on learning. I love how it caters for all students learning styles.

- *I am a late career teacher who has a degree in Science. I also studied graphic design (incorporating web design). Therefore, I am quite a confident user of technology and media. I need to learn more about how to harness the strength*

of the available technology to improve student learning outcomes.

- *I think there is always more to learn!*
- *Best ways to teach and engage students*
- *The best ways to integrate STEM in a meaningful way across grades, particularly with young students, where to get the best training to be able to teach it effectively and learn about the resources.*
- *I have been teaching STEAM in our school for the last 4 years. I have found the students to be fully engaged in every lesson. It is the most rewarding subject to teach as ALL children can participate. It is "hands on" relevant learning to set our children up with the skills they will need in the future.*
- *Always something new to learn and creative ways others implement STEM into their teaching*

The post-survey findings of variables 1 (Attitude) and 2 (Interest) were highly positive. As the tables below show a further increase in these two variables was observed at the end of the project. For instance, in the pre-survey, 92% of teachers said that technology integrated into lessons provide an advantage (item 1), whereas 96% of them agreed with the statement in the post-survey. Also, interest in teaching STEM (item 1 of variable 2) increased from 95% to 97% in the post-survey. These findings could indicate that teachers' involvement in the STEMShare Community Project enhanced teachers' attitude and interest towards STEM. However, as will be explained below, a T-Test was required to understand if this increase was by chance or due to the impact of the project.

Variable 1: Attitude	Mean Pre	Mean Post
1. Technology integrated into lessons provide an advantage	4.35	4.49
2. STEM will help my students understand the world around them	4.41	4.52
3. It is important to integrate STEM learning objectives into curriculum	4.42	4.56
4. It is important to teach students about STEM	4.54	4.56

Variable 2: Interest	Mean Pre	Mean Post
1. I am interested to teach STEM	4.47	4.56
2. I would like to know more about teaching STEM effectively	4.38	4.49

In addition, the post-survey comments made by teachers suggested their favourable attitude and deep appreciation for the project. They voluntarily discussed its benefits to students and themselves and highlighted the strengths of the project including "providing lessons and tips" and "improving student engagement", "top quality resources", and "supportive STEMShare Leaders".

This has been one of the best means of upskilling teachers and enhancing knowledge of STEM by provision of terrific resources. Students valued it and so did I. More of this though as now my appetite is voracious to improve my skills with using them often.

- *Kids and myself loved it!*
- *The online resources were useful for providing lessons and tips for creating experiences. Having one of the stem leaders come and visit the school was excellent to see how it can be integrated and taught by someone with deep knowledge.*
- *It was a very rewarding educational experience.*
- *Having the kit made things possible that would have never been without it. It helped without project in the first Lego League, it engaged all students in the school when exposed to it. However, most importantly was the effort and training from …. Her support and effort was outstanding. She was always available for help…*
- *The one day seminar allowed me to really get my head around what each of the kits contained.*
- *Thank you so much for the opportunity to enjoy and utilise all of the fabulous resources!*
- *Amazing initiative! Thank you.*

The STEMShare program was an outstanding success at our school. as a community we grew in our knowledge and willingness. Their collaboration and professional dialogue as staff shared their ideas, successes and failures.

- *It was a great reference point to be able to access for necessary information.*
- *The tutorials are easy to follow and give all teachers the confidence to implement ICT, equipment and challenges-it was brilliant!*
- *….was amazing and so supportive as a STEMShare leader. I feel very enthusiastic about the new possibilities!*
- *The STEMShare Kit allowed us to experiment and explore the use of STEM resources before investing in our own. A fabulous way to empower staff as they become more informed with the availability and potential uses of such resources.*
- *This program was an amazing experience for my students and teachers at my school. We are a small school and could not afford the level and quality of resource in these kits, so we are very grateful for this opportunity.*
- *Outstanding PL by the STEMShare team*
- *I found the experience very overwhelming initially however when one of the STEMShare Leaders visited our school we were able to really delve into the most relevant aspects of the film kit.*

I was really nervous to start using the 3D Printer BUT am completely smitten with it now!! The students LOVED Tinkercad, they were totally engaged and were so good at it. They learnt it up so quickly and they are now teaching ME so much!! Do not be afraid for your students to outstrip you, it is a wonderful learning tool when they can teach their peers!!

- *This is an outstanding initiative especially for disadvantaged schools with limited access to expertise or resources.*
- *The support from the STEMShare leader was also great. The students were totally engaged and couldn't wait to design and code with the robotic kits.*

I was very impressed with the level of resources provided by the STEMShare team, I tried to communicate my enthusiasm to my colleagues but you can only lead a horse to water, you can't smack it round the head with a computer. Borrowing the kits has provided a core of teachers with some great inspiration, hopefully the others will come on board when they are ready.

The third variable under study was teachers' STEM self-efficacy beliefs (i.e. teachers' beliefs in their own ability to teach STEM). The pre-survey ratings revealed that, unlike variables 1 and 2 that had high ratings at the outset of the project, variable 3 was rated relatively low and teachers tended to take a "neutral" to "agree" position on most items before the project. For instance, only 47% assumed they were equipped with the right knowledge to teach STEM (item7). Also, only 56% of teachers asserted that they knew how to learn about STEM teaching (item 8), and 36% were either unsure or disagreed that they could answer students' questions related to STEM (item 2). This finding is not new; previous research also shows teachers, especially primary teachers, perceive to be "unprepared" and "lack confidence and efficacy" for teaching STEM content (Bleicher, 2006; Settlage, Southerland, Smith, & Ceglie, 2009). Yildirim (2016) also observed that although teachers had positive views about STEM, they were not adequately knowledgeable about STEM education. This lack of knowledge could create doubts in one's ability to teach STEM concepts (McDonald, 2016), as evidenced by the low ratings of STEM self-efficacy items in this research. The pre-survey commentaries added support to the observation that teachers had low STEM self-efficacy beliefs and confidence in teaching. The majority of teachers argued that they needed "face-to-face" training, "new ideas", "lesson plans linked directly to the new curriculums", "more PL", and "a step by step program of stem lessons". The examples below show teachers' lack of STEM confidence and self-efficacy prior to implementation of STEMShare Community project:

- *Being on kindergarten for a few years I haven't really had the opportunities as yet to broaden my knowledge around STEM in the higher grades as yet. I would probably lack some confidence if I was to go back to stage 2 or 3 next year as I feel I've missed some learning relating to STEM and best supporting students in STEM.*
- *There are facets of science, technology and maths of which I'm far from expert, and in every classroom there is at least one student who is far more capable.*

I am so concerned to the point of being unwell overthinking of teaching it... I am just getting thrown in the deep end and we will have had the lesson stuff that has come in the email and that is all the 'training/help' I have received.....

- *I am more comfortable programming that actually using STEM in teaching. I need to have my ability and expectations expanded. Having new ideas and seeing how technology can add to student learning is what I hope for.*
- *Remote location. Value face to face in services where we do as well as listen.*
- *I feel like I need some assistance to see how it could work effectively for all type of learners- particularly students who aren't independently driven to reflect on learning.*

I would really like access to lesson plans that link directly to the new curriculums and integrate stem. Ones I have found are often above the level of the students, not very engaging or have little relevance to the students. It is very time consuming to regularly create lessons and look for resources to support them. This puts a lot of my colleagues off and with such a packed curriculum this is understandable.

- *I have a sound understanding of teaching STEM, but my knowledge of robotics and coding is limited. I hope that through the STEMShare kit, I am able to develop this.*
- *I am passionate about incorporating technology into everyday lessons however feel alone on this within my school environment. Would be good to meet with other leaders in STEM and learn from them.*
- *How do you program for it I have incorporated a lot of hands on activities into my classroom but still find it hard to program for it.*
- *More PL is always helpful.*
- *The more information you can access, the better.*
- *It would be good to have some professional development to integrate STEM better in everyday teaching.*
- *If provided with a step by step program of stem lessons and technology lessons I and others would be better equipped to successfully teach it.*

The post-survey data indicated a major boost in teachers' STEM self-efficacy beliefs. As the table below suggests, the mean scores of all STEM self-efficacy items improved at the end of Term 4 as teachers engaged in professional learning and gained hands-on experiences. For instance, whereas only 60% of teachers said they were able to answer students' questions related to STEM (item 2) in the pre-survey, 84.5% agreed with the statement in the post-survey. Another significant increase was observed in item 7 where only 46% (Mean= 3.27) of teachers stated that they had enough knowledge to teach STEM before the project. After implementation, a remarkable 70% of teachers agreed (Mean=3.75).

Variable 3: STEM Self-efficacy	Mean Pre	Mean Post
1. I have confidence in my ability to teach STEM	3.61	4.11
2. I am able to answer students' questions related to STEM	3.59	4.08
3. I can help students who are confused about STEM subjects	3.73	4.16
4. I can help my students value STEM learning	4.14	4.45
5. I can engage students in STEM activities	3.93	4.36
6. I am confident integrating technology into my lessons	3.83	4.16
7. I have enough knowledge to teach STEM	3.27	3.75
8. I know where to go to learn more about STEM teaching for myself.	3.50	4.00

As the table below shows the mean scores of each variable increased from pre to post evaluation, while the mean of STEM self-efficacy had the highest increase.

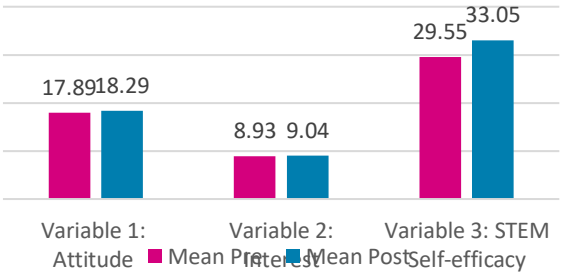


Table 3. Mean scores of each variable in pre and post surveys

3.2. PAIRED SAMPLES T-TEST

Although the mean scores of the three variables increased from pre to post evaluation, without T-test we would not know whether the obtained differences between the means were statistically significant. More specifically, a Paired Sample T-test is used when we wish to compare two means of the same groups in order to state "with some degree of confidence that the obtained difference between the means of the sample groups is too great to be a chance event" (Siegle, n.d.). The greater the difference between the two means, the greater the likelihood that a statistically significant mean difference exists.

Usually the size of the sample has a determining role in data analysis. In other words, when the sample size is larger than 30, the means tend to become more stable representations of group performance while a sample size smaller than 30 does not produce reliable data. Given the large population of teachers (N=245), a reliable outcome was expected. The T-test was run and it was found that the increase between the overall mean scores of pre and post-surveys was statistically significant as the Sig value was less than 0.05 (sig=00<0.05). Universally, when the Sig value is less than or equal to 0.05, we can conclude that there is a statistically significant difference between the two conditions and the differences between means are due to the implementation of a specific program and not likely to change.

		Mean	N	Std. Deviation
Pair 1	Sum-pre	56.3959	245	6.69003
	Sum-post	60.4000	245	6.09447

		t	df	Sig. (2-tailed)
Pair 1	Sum-pre – sum-post	-6.390	244	.000

Paired Samples T-Test on mean scores of pre and post surveys

Now the question is does the shift in the overall mean score attributable to all the variables or to only one or two of them because sometimes despite the increase in the mean scores of all variables from pre to post evaluation only one or two variables reach a statistical significance and they contribute to an increase in the overall mean score. Hence, another T-test was run on each variable separately and it was found that the differences between the mean scores of variable 1 (Attitude, Sig=016<0.05) and variable 3 (Self-efficacy beliefs, Sig=00<0.05) were statistically significant (i.e. sig=<0.05). In other words, the project did improve teachers' STEM attitude and self-efficacy beliefs in the course of the project. However, the T-test revealed that the Sig value for teachers' STEM interest was less than 0.05 (Sig=0.256>0.05). This outcome indicated that the difference between the mean scores of Interest was not statistically significant and the increase in the mean score of the post-survey occurred only by chance, meaning the program had no impact on teachers' STEM interest.

3.3. TEACHERS' REFLECTIONS ON PROFESSIONAL LEARNING

Section B of the Teacher Survey assessed teachers' satisfaction of the professional learning (PL). This section was unique to the post-survey as teachers had not received any PL at the time pre-surveys were administered. As Table 4 shows, 85% declared themselves satisfied and dissatisfaction level was as low as 5%.

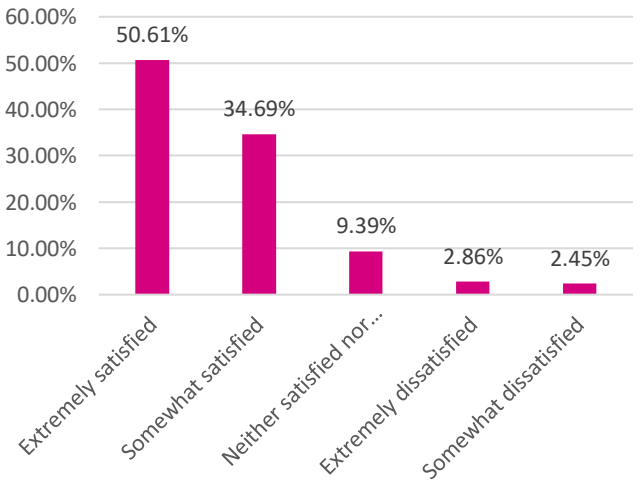


Table 4. Teachers' ratings of professional learning

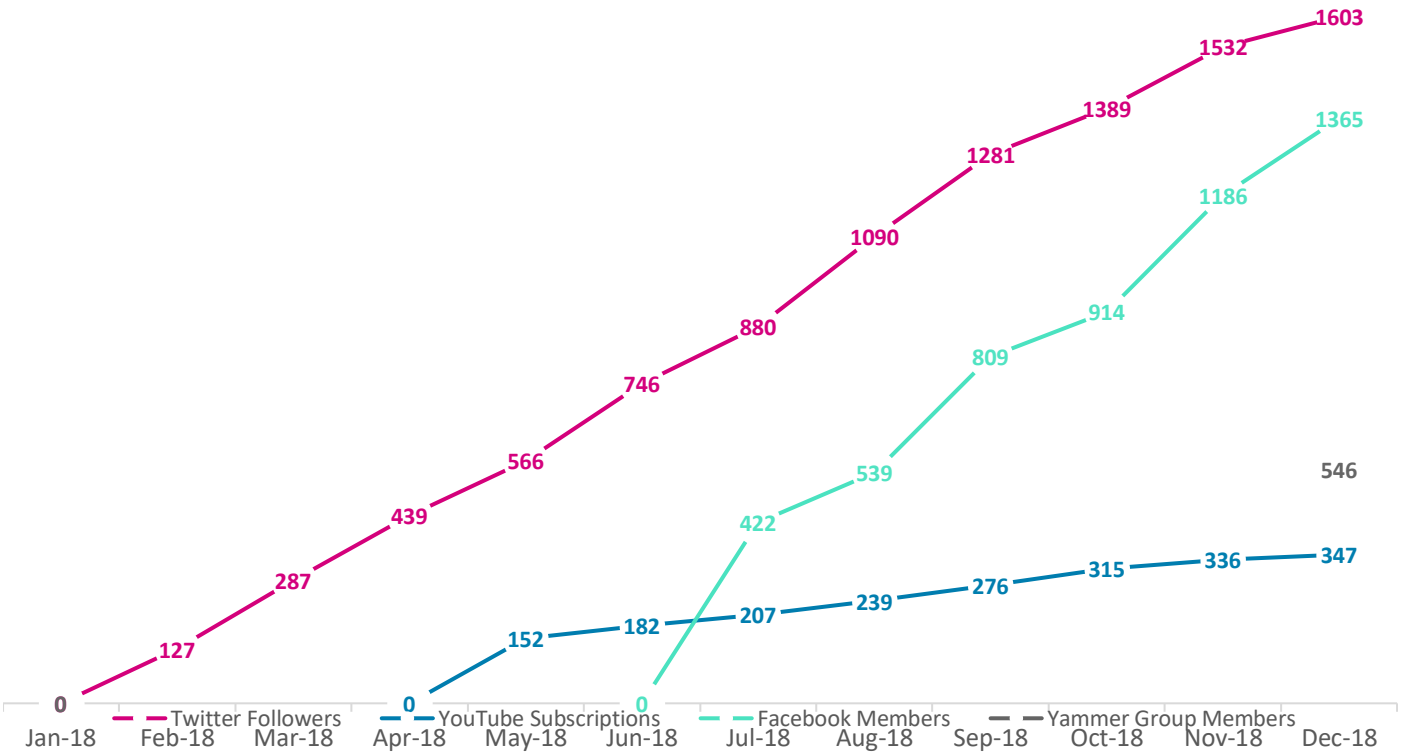
When asked to rate different aspects of the PL, "Resources and Learning materials" topped the list (Table 5), with 93% (M=4.43) showing immense satisfaction. It is interesting to note that in the pilot phase of the research

conducted in Term 3, 86% of teachers (M=4.14) had agreed with this item, which was the highest rating across PL items. In Term 4 we observed even a higher satisfaction with this item. Although the research population in terms 3 and 4 were different and comparing the mean scores of two different research groups could not serve as an accurate indicator of the extent of improvement in the participants, it was likely that the enhancement of the resources and learning materials provided to teachers in Term 4 led to an increase in teachers' satisfaction level. Items 2, 3, 4, and 5 were rated highly by teachers as well, with over 70% agreeing with these items. As Table 5 shows, the ratings of almost all items increased from Term 3 (pilot phase) to Term 4 (item 4 was a new item that was added to the Term 4 survey), which indicated noticeable improvement in different aspects of the PL.

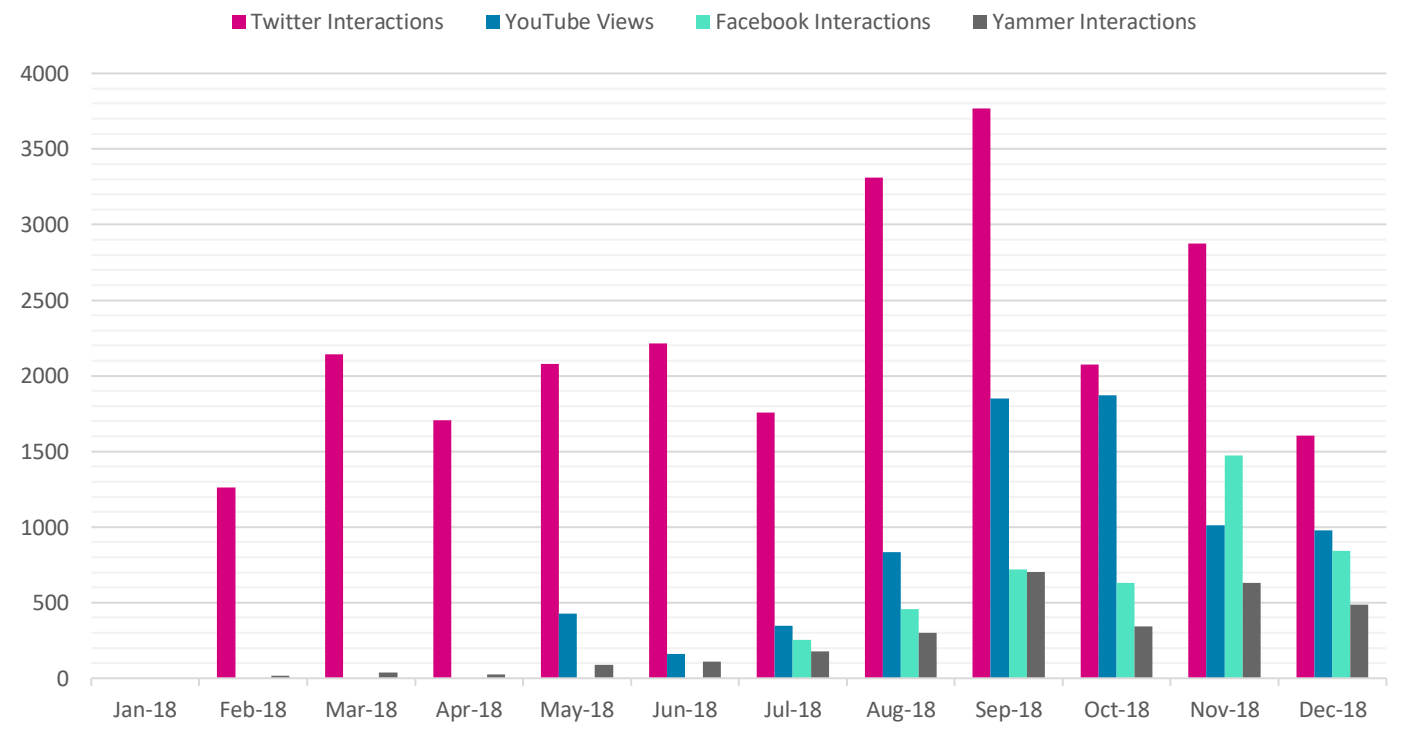
The only decline was in item 7 from M= 4.00 in Term 3 to M=3.82 in Term 4. Interestingly, the two items that measured teachers' satisfaction of STEMShare leaders were rated moderately low. The reason for such rating is explained below. Amongst the items above, Item 8 had the lowest rating (M=2.91), where only 37% agreed with the assertion. A comparison between the ratings of Term 3 (M=2.84) and 4 (M=2.91) suggested a slight increase in the collaboration between teachers from different schools. What might have contributed to this rise are the interactions and collaborations fostered through social media among teachers, which as depicted in the graphs below, maintained upward momentum towards the end of Term 3, and remained stable throughout Term 4.

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

Table 5. Mean scores of PL subscales



Graph 1. STEMShare community social followers' growth



Graph 2. STEMShare community social interactions

As mentioned above, teachers participating in this research were of the belief that the STEMShare Community project contributed extensively to upskilling their knowledge and confidence in teaching STEM as the ratings of the variables, discussed above, suggested. Without a doubt the PL played a major role in preparing teachers to implement the STEMShare equipment effectively. However, in order to understand the impact of other contributing factors, teachers were prompted to rank the items below in order of their effectiveness in helping them use the kit equipment for student learning. As Table 6 shows, social media and Leaning Library received the highest ratings and teachers pointed out that they were "terrific resources", "outstanding", and "concise and extremely helpful". A few examples from the commentaries provided for this section are presented below.

Items	Mean
1. Social Media	5.08
2. Learning Library	4.28
3. Support from STEMShare team including PL	4.15
4. Support from school	4.07
5. How-to-videos	3.70
6. Collaboration with other teachers	3.38
7. STEMShare leaders' one-on-one training	3.34

Table 6. Mean scores of factors contributing to teachers' STEM readiness

- *The STEMShare Library is absolutely wonderful… the teaching resources are easy to follow.*
- *The learning library and videos were a terrific resource!*

The STEM share library and accompanying resources are outstanding.

- *The library was super easy to use and had us up and running on VR in minutes*
- *Love all the collaboration- social media and YouTube.*

The lessons provided on the library are well integrated and enjoyable for the kids

- *The videos in the STEMShare library were concise and extremely helpful for teachers to get started using the kits with purpose.*
- *The learning resources from the online library are invaluable.*
- *Excellent lessons in library.*

Online programs and social media were the most helpful. We were able to find ideas through social media and implement lessons based on what we saw others do.

The lowest rating amongst the items of the above table was given to item 7 at 3.34. This was the second time that teachers tended to be slightly critical of STEMShare leaders' one-on-one training, which was an interesting finding because it would beg the question whether teachers were dissatisfied with the quality and frequency of the training they had or they did not attend any training in the first place. Based on the commentaries made by teachers in this section, it was found that the latter was the case and some teachers had not undergone any training. Given the ratio of Term 4 schools (N=526) to STEMShare leaders (N=10), it was not surprising to find the one-on-one training had not reached all schools, as the narratives below suggest. However, in Term 3 (i.e. pilot) there were only 35 schools involved and they all had the opportunity to benefit from leaders' one-on-one support. Hence, it was expected to observe higher satisfaction on the part of Term 3 teachers with regard to STEMShare leaders.

- *We did not receive any one on one training or additional support from the STEMShare team apart from emails and the link to the library.*
- *We did not do any one on one training, this would have definitely helped. There were potentially too many emails that got confusing.*

- *I did not participate in one on one training.*

Not sure what the Learning Library is or who STEMShare Leaders' are. I was not aware that there are How-to videos that could be watched. Also not sure what PL was provided (I recall maybe an email link to an online session but I did not attend). Support from my stage partner, online programs and social media were the most helpful. We were able to find ideas through social media and implement lessons based on what we saw others do.

- *I felt that the stem share leader did not have enough time to explain how to use the equipment or let us have a go at using something we have never seen before.*
- *After the initial STEMShare PL day - which was great and motivated a lot of new thoughts and teaching ideas, I didn't find many resources to help introduce the use of dash/tablet kit into my Stage 3 classes.*
- *It would have been beneficial to receive time off class to prepare for using the kit. The videos were short, but good. More training of some sort would have been good.*
- *We did not receive any one on one training hence its low rating but two of us attended the unpacking the kit workshop which was helpful was the one providing the support at school so gain why it has a low rating for me.*
- *We didn't receive the one-on-one STEMShare leaders training. However, considering the impact from the group sessions I imagine it would be up there.*
- *I did not receive one-on-one training from STEMShare Leaders, and as such cannot comment on its effectiveness.*
- *I cannot rank the one-on-one training as I know nothing about it nor was it an option given to me.*
- *We received no one-on-one training from STEMShare Leaders at all; we weren't contacted at all during the whole process to see how we were progressing.*
- *One-on-one training was not provided. I work at a two-teacher school and I was the only teacher using the kit.*

I didn't utilise most of the above. It was too much for me to absorb all in one day and I immediately forgot how to access most of the online resources. I know I am a dinosaur, but a paper booklet full of useful websites or contact would have been really useful.

3.4. CHALLENGES AND BARRIERS TO USING THE KITS EFFECTIVELY

The third section of the surveys probed potential challenges and barriers to using the STEMShare kits. Although it was found that teachers raised the same issues in pre and post surveys, the content analysis conducted on the commentaries revealed some changes in the responses from pre to post evaluation.

3.4.1. LACK OF KNOWLEDGE AND CONFIDENCE IN USING TECHNOLOGY

It was previously discussed that teachers participating in the pre-survey had low STEM self-efficacy beliefs. Interestingly, they identified their own lack of STEM knowledge and low confidence in working with technology as the main barriers to using the STEMShare kits. More specifically, prior to the project, teachers felt "anxious", "scared", "nervous", "overwhelmed", "uncomfortable", and "worried" as they thought they had limited knowledge of technology. They stressed that they needed professional development to upskill themselves and develop the confidence to "go beyond just 'building stuff'" and "surface level teaching". The examples below show teachers' lack of confidence identified as the main barrier before the implementation of the program:

- *A challenge could be my limited knowledge and understanding of technology and engineering.*

Not understanding the 'fine workings' of things like Ozobots etc. Having no knowledge of coding. I am capable with most computer functions, but the new technologies are amazing but scary to an older person

- *I feel I require additional training in this area*
- *My own knowledge (or lack thereof).*
- *As an older teacher I don't have the skills that are required or needed to teach STEM even though I*

would like opportunities to learn more about it. Professional learning around STEM is often released 'softly' so that teachers don't always know what's available.

- *Teachers not having experience or much expertise.*

Teachers can be very anxious about STEM, can feel overwhelmed by the breadth of STEM and the pace with which the field of STEM changes. We need to continue to support all teachers to develop confidence and capacity to embed STEM into their classrooms.

- *Not having experience or a great deal of confidence in the area as of yet. Not knowing the content to teach.*
- *I am teaching a support class with very limited ability to engage in the levels of critical thinking and computational thinking involved in many STEM activities.*
- *Some teachers are scared or not comfortable in teaching STEM.*
- *I am worried if something goes wrong and I do not have the understanding to fix it.*
- *being able to teach to a variety of students and their academic levels*
- *My lack of knowledge*
- *Being aware of the different complexities of the types of lessons that can be taught.*
- *Finding new projects to engage the students which are relevant to the students knowledge.*
- *We also need to keep training and upskilling ourselves to meet the demands of 21st century.*
- *Understanding how to integrate technology meaningfully into everyday lessons rather than a stand-alone experience*
- *Probably my own knowledge in it. Just getting my head around first before I can teach it engagingly and productively to the students.*
- *When you are not fluent with it's uses, you don't really understand what bits you will need to be able to pull an activity together.*

Knowledge of how to use the resources and then access to certain resources that are required to implement it properly.

- *I don't know if I should call is STEM or STEAM. I thought it was STEAM now, with the element of the arts being added. I think there should be more PL around how to incorporate STEAM into our programming.*
- *Lack of knowledge on the different types of technology, things change so fast*

I just don't really know exactly what STEM is or looks like in the classroom.

- *The biggest hurdle/barrier is developing confidence in regularly using STEM as part of my science program, changing a way of thinking and developing skills through PL to support my learning to enable me to engage students in quality STEM learning.*
- *My knowledge about such technologies as VR*
- *Having the equipment and tolls to teach STEM.*
- *Learning the content before teaching it myself*
- *Lack of knowledge and equipment.*
- *Not all students and staff are confident with this type of teaching/learning.*
- *Using the variety of new and different technologies*
- *knowledge and ideas*
- *I hope I have enough knowledge.*
- *lack of knowledge regarding stem. How to go beyond just 'building stuff'*
- *deep knowledge of stem for the teachers, not just surface level teaching*
- *lack of confidence; less familiar with technology aspects of syllabus.*
- *Staff not being trained to teach STEM effectively.*
- *If the teachers are not confident and competent in teaching STEM this will then affect the student's motivations towards learning and engaging.*
- *My ability to understand what is required - however I am interested to learn as much as possible. I am the LaST and only employed 2 days per week so time is an issue.*
- *Keeping staff updated on new curriculum*
- *Lack of prior knowledge to support student engagement.*
- *Hopefully after working with the STEM teacher my confidence will grow*

Learning about new technologies at a slower rate than my students. Conversely, I am looking forward to letting my students teach me what they know and pick up quickly.

- *That I have very limited knowledge in this area and will therefore be learning with the students.*
- *I don't want to be the expert, more the facilitator but still need to know enough to help those less confident students.*
- *What STEM is, how I can use this learning within my teaching program and ideas/activities to use*
- *I am rather nervous of using the 3D printer as I have done a short course on it but still don't feel fully familiar with it. There is a lot for me to still learn but together with the children we will enjoy it!! The children know so much about technology that I am sure they will grasp TinkerCAD pretty quickly!*

At the conclusion of the project when the same teachers were asked to reflect on the challenges they encountered, only a small number still referred to their lack of knowledge as the main barrier. Most teachers appeared confident in using the STEMShare equipment although they mentioned they struggled initially. However, they were able to overcome this challenge as they "collaborated with their peers", "watched videos", "had a go", "got comfortable with the kit", and used "social media" to find answers to their questions:

Just getting used to the technology, and having a go, because it's new for me, but collaborating worked well.

- *It was a rapid learning curve for me but online training was great with videos I could sit and watch to get started.*
- *Lack of knowledge but easily resolved with peer help*
- *Lack of knowledge with some of the kit. Having to teach myself how to do it. You have to actually play with it to get comfortable, but still need to develop my own knowledge.*

My lack of knowledge at the beginning but as we progress both I and the students learnt together.

- *Basically, used social media to find out more about how to use the kits.*
- *Working out how to use TouchCast. The explanation videos of how to put the kit together were useful, as well as some of the resources of suggested activities to use with the filming kit.*
- *I had to watch a number of videos and read through an instruction manual before eventually finding my answer from a Yammer group. However, it taught my students and I perseverance in our STEM journey.*
- *Understanding how to use some of the kits and how to integrate them into lessons (although the social media and google searching pages helped).*

3.4.2. TIME CONSTRAINTS

The next challenge discussed by teachers in both pre and post surveys was "time constrains", suggesting that teachers were able to predict this challenge at the outset of the project and actually encountered the same challenge when using the STEMShare equipment. Similarly, other studies found that the main challenge teachers faced in integrating STEM was mainly teachers' negative perceptions regarding integrating STEM into "an already crowded curriculum" (Coffey & Alberts, 2013; Roehrig, Moore, Wang, & Park, 2012) as also suggested by the teachers in Term 4. In the pre-survey, they pointed out that they needed to "plan", "research content", "prepare lessons and resources", and "refine and reflect on the lessons" and lack of time would be "the biggest barrier". Below are some of the examples from pre-surveys:

- *I find that we as teachers don't get enough time to teach STEM and balance it out with other KLAs.*
- *Preparation time*
- *Time constraints in an already packed curriculum*
- *Timetabling*
- *Time in a crowded curriculum.*
- *It often feels like you have to step in too early, to get to the solution, in order to meet the time constraints of daily life in the classroom.*
- *Time for planning.*
- *Limited time for me to prepare through my own PL.*

- *Lack of time to explore STEM learning for myself*
- *Time to program and plan STEM teaching and learning activities.*
- *Time and access to resources*

Time to plan and integrate STEM into the crowded curriculum - trying to teach STEM as a separate aspect is too difficult with regard to time and will work much better when integrated into our curriculum. Alternatively, making time available to focus on STEM teaching by reducing other areas of Science, Maths and / or English would be advantageous.

- *Lack of time to provide enough professional learning for all staff members.*
- *The time taken for teachers to be able to develop high quality STEM units. The time taken and the challenge of developing quality assessment practices for STEM units. Understanding how to apply Visible Learning to inquiry-based learning.*
- *Time limit: to be able to teach STEM explicitly.*

Time is the biggest barrier - to devote more time to STEM means something else has to be left out - also, am more interested in getting their literacy skills up to par.

- *Time to properly plan time constraints in class teaching time*
- *Time to tech if effectively to ensure it is used properly.*
- *Crowded curriculum*
- *Time to engage in learning about resources and how to teach and use STEM effectively in the everyday classroom.*

Time to research content and prepare lessons and resources.

- *Crowded curriculum and trying to do more. I understand that it should be integrated into what you do but time is a big issue.*
- *Time to prepare lessons & resources during work time. Time to discuss, reflect and share experiences, resources, learning etc during work time.*
- *Overcrowded curriculum (Heavily focussed on English & Mathematics)*
- *Curriculum content so crowded; monitoring processes inhibit reflexive curriculum decisions*
- *Time factors of an already crowded curriculum and stem can sometimes seen as 'another extra'.*
- *Time to refine and reflect on the lessons and the successes of using stem in the classroom.*

At the end of Term 4, again teachers pointed out that time was their main barrier. They stressed that Term 4 was way too busy and they needed more time to "integrate the kits", "implement a proper effective program", "support other staff member", and "engage students in long term projects":

- *Time restraints, I wanted to put it out there more in the school, but I didn't have the time to support other staff member as much as I would have liked to.*
- *Not always time to try out the resources, to best know how to use them.*

I found the time frame with the kit to not be long enough. With a 3D printing unit, the students need time to design their project which can take multiple weeks and by the time we were ready to print we had an email saying our kit was about to be picked up (not a full term with the kit either). This became a challenge and we needed to negotiate with the next school.

- *The time frame wasn't really long enough to get our heads around using them and then implementing a proper effective program. The training got offered well after we already had the kit. The training would be more effective long before kits arrive.*
- *Only time. It was a busy term.*
- *Time- we could have kept printing all the time---needed longer. Will definitely need to re-book.*
- *My only barrier was the time as I had to teach it in the weekly one hour slot.*
- *Time - with everything else that is happening in the school during term 4 (eg. end of year presentation)*
- *Finding time to allow student to familiarise themselves with the equipment before using the learning challenges in a short period of time, perhaps extend the loaning time..*

- *Timetabling - arranging for adequate time with kits amongst other staff Lesson planning - new topics/technology*
- *Calendar was way too crammed to utilise these fantastic resources. Had ideas but without time to learn, skill up and then use with students.*
- *booking a time to use them*
- *Timing - we didn't use the kits with our students right away and felt like we could have done with some more time.*
- *Just time to fit the lessons in around all the other parts of the curriculum. It would be great to allow 0.6 of the curriculum to be STEM and coding given that will be a core component of their future world.*

Time is always a barrier. I taught across the school but only had 1 day per week allocated. Need more for all of the equipment as had students engaged in long term projects - eg. learning how Makey Makey kits worked, then designing own creation, then testing, then presenting.

- *There were 3 types of robots. Across the term, we really only got to embrace and learn about 2 of them. So I suppose having the kit for more time would've have helped.*
- *Not enough time to learn about the kit before it arrived-time restraints because of other commitments-need more off class time to prepare.*
- *Giving the students enough time to problem solve was a timetabling issue that we needed to solve.*
- *Not enough time in term 4 because it is such a busy term.*
- *Would be better if they were at the school for most of the term. Pack up week nine arrive week ten so they can be used by teachers before the students, this creates opportunities to explore in the holidays.*

The only challenge was finding as much time as possible to allow my kids to use the kits. Our programming was already complete for that term so if we ever get to use them again it would be better for us to plan our term with the kits in mind so we can integrate them into our units of work.

3.4.3. Technical issues and lack of resources

The third challenge teachers foresaw at the beginning of Term 4 was "technical issues". A large number of comments focused on unreliability of technology including "wifi and technology breaking down", "slow internet", "technical difficulties", "troubleshooting problems", as well as "number of devices per student", "sharing the kit with the rest of the school", and having limited access to equipment such as a science lab:

- *Technology failures make teaching STEM hard - not having enough resources to use in a class situation or network/ devices failing during lessons and causing disruption. Not enough technicians to keep stuff running. Another barrier is not having enough time to let the kids explore/problem solve for themselves.*
- *Not enough resources for whole class.*
- *Access to fully functioning computers. Reliable internet.*
- *Lack of resources*
- *School resources*
- *Access to technology and consistency across the school*
- *Resources not working, lack of technology*
- *Lack of equipment.*
- *Finding/purchasing resources the chaos is hard to manage at times*
- *Functioning IT when required. resources*
- *Facilities in primary schools can be more limited (e.g. no Science lab or specific/dedicated areas).*

Teaching stem has become easier this term with the STEMShare kits. The students i am working with are really engaged and are beginning to problem solve. I have also noticed that they often ask other students to help before they ask for help from me. I think the difficulty will come when we don't have as much equipment and still trying to maintain the student's engagement level.

- *We have very little access to technology for STEM lessons. A set of 40 iPads between 920 students is*

virtually the extent of our technology. I teach a Gifted and Talented selective class and would love access to more technology. I have to adapt my stem lessons to recyclable materials and cheap things I can purchase as there is no budget available for this.

- *Enough resources in a big school.*
- *Functioning of technology - (is it working)*
- *Lack of reliable technology*
- *A consistent connection to the wifi network are two issues I foresee.*
- *In kindergarten, logging in to computers is a huge barrier.*
- *Lack of resources. I would love to be able to borrow more than one kit per year.*
- *Space, cost and resources*
- *Cost of technology and internet reliability.*
- *Access to resources*
- *Having enough resources for the class to use.*
- *availability of hardware*
- *The technology sometimes not working.*
- *Trouble shooting with technology.*
- *Access to ongoing, updated technology. Given the pace in which technology dates, it is difficult to maintain a base of new, cost-effective technology resources.*
- *Not having the adequate resources and training*
- *Availability and accessibility of technology*
- *availability of resources*
- *Access to equipment*
- *Access to technology in the classroom. We only have 45 iPads to share in a school of 960 students.*
- *Equipment and infrastructure Embedding into the curriculum*
- *Not all schools have access to enough equipment for their students, which means time is wasted building, dismantling, then re-building projects.*

Student access to technology - small number of technology types which need to be shared by large groups of students, e.g. 6 iPads per class or 2 Spheros per class. Kids need small group experiences to ensure they're actively engaged. Limited range of technology - technology such as 3D printers, Spheros & iPads are expensive so schools can't afford to buy everything that's available.

- *Lack of technology and equipment to use*
- *Issues with technology- not enough equipment/not working etc.*
- *Technology not working - hard to get resources*
- *Access to appropriate resources and at an appropriate student ratio e.g not 1 robot between 10 students.*
- *Resources and availability of equity for big schools*
- *Organising the equipment, making sure it's charged and functional at the time of need.*
- *Slow internet and software updates.*
- *Lack of resources that work*
- *Technology technical difficulties Resources*

A lack of resources for some schools and it is a long process to implement technology into classroom lessons/programs.

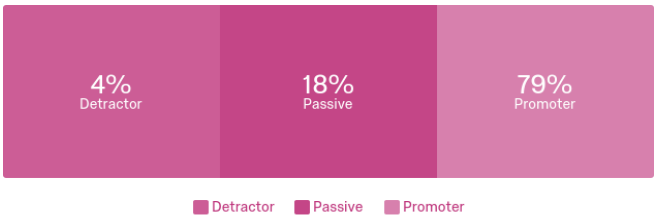
The same theme (i.e. technical issues) emerged from the post-survey data at the end of Term 4 and teachers remarked that they confronted challenges such as "charging the components", "Wi-Fi connectivity", "keeping track of the elements of each kit", and "not having enough equipment":

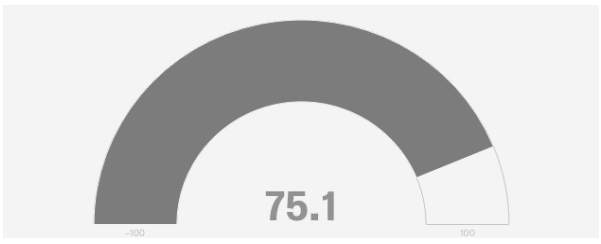
- *I had some technical issues with 1-2 of the mobile phones in the Primary VR kit which would not connect to detnsw network which made updates slow/impossible and affected use during lesson time. In addition, I found poly.google and the VR headsets flakey when we had created our own content.*
- *Making sure the components were charged and ready for the next lesson. Keeping track of where elements of the kit were at any one time.*
- *We had to label and name all of the dash bots so that they didn't get mixed up or confused. The bots constantly disconnected and reconnected throughout lessons when using the blue bots some students created pathways for it to follow on the ground, but when we pressed go on the app the blue bot would run into the 'wall' on the app (side of the screen) and wouldn't move forward on the ground. I wasn't sure how to get around this.*

- *The tablets seemed to show they were connected to our school Wi-Fi, however, we couldn't access the internet or share 'keys' in the Wonder app*
- *The VR phones came offline several times. Updates confused them even more.*
- *A few missing pieces in the We Do kids*
- *Charging was a barrier. They were booked out solidly some days so if you had the last hour they could begin to go flat*
- *Not enough equipment to cater for class sizes in stage 3.*
- *Lots of pieces*
- *Not losing little Lego pieces*
- *The iPhones were not working properly at first.*
- *No easy way to update apps. Some apps didn't work. Some of the equipment such as the 3D camera in the VR kit required further instructions.*
- *3D Printing - finding time to print complex models for a large number of students. Having to balance student expectations against reasonable printing timeframes.*
- *Too many students to effectively use the filming gear.*
- *PCs ran out of battery*
- *Number of devices available.*
- *Initially lacked enough iPads to support products.*
- *To have full student participation you need to add 5 more kits to each area of the robotics kit. The students need to work in pairs to maintain full engagement. In Stage 3, where class sizes are 30+ there weren't enough kits.*
- *The usual student management and sharing issues with students who are on the spectrum.*
- *Our Internet connectivity caused a huge issue. Until our school has the connectivity fixed we are limited to how we use STEMShare kits. We were excited - students and staff about using the kit but once again out internet is a problem. Just another example of how our students are dis-advantaged again with the use of technology.*
- *not losing any of the tiny Lego.*
- *Connectivity issues to iPads*
- *Ensuring that items were charged before each use*
- *Robotics not working. One Dash did not work (kept powering off and then only turning one direction) and it was replaced but it took about two weeks.*
- *Wi-Fi sketchy for iPhone / Apple devices. This inhibited use and connectivity for Apps.*
- *Having only 10 laptops and 40 kits was difficult to manage.*

3.5. NET PROMOTER SCORE

As a final exercise teachers participated in a Net Promoter Score (NPS) activity to record their likelihood of recommending STEMShare Community project to other teachers by assigning a number from 0 (not at all likely) to 10 (Extremely likely). A 9 or 10 would mean the respondents were most likely to recommend the program to a colleague, so they were promoters. A 7 or 8 would group the respondents into a passive category and an answer below 6 would suggest the respondents were detractors and would not recommend the program. The NPS range is between -100 to +100 where a NPS above 0 is considered "good", +50 is "excellent" and above 70 is "world-class". As the chart below shows the NPS recorded by teachers in Term 4 was 75.1, which was exceptionally high and indicated an overwhelming 79% were promoters of the STEMShare Community project. The NPS recorded by teachers in the pilot phase of the research was 63% and only 68% were promoters. An increase in the NPS and the number of promoters in Term 4 highlights a remarkable improvement in different aspects of the project leading to an immense satisfaction on the part of teachers. The comments made by teachers in this section confirms this point:





- *The kits are easy to use regardless of your experience with technology. The students were highly engaged and produced a final product.*
- *Had some great experiences in the staff learning and supporting Year4 in the STEM day. The virtual reality samples fit with what we had been studying in Learning Support.*
- *I had online information and also a very rapid backup when I needed additional answers to my questions.*
- *The resources were great and the variety of kits available caters to a large ranges if interests and ages*
- *Kids and myself loved it!*
- *The program is an outstanding initiative providing technology to schools and students who may not otherwise have access.*

The process was smooth and seamless, supported with effective lessons, ideas, collaborative groups and the whole process was easy.

- *I think it made a real difference to student engagement, creative a, critical thinking and problem solving. We were also able to involve parents and community with STEM knowledge.*
- *A resource my students would not have been able to experience without STEMShare. Their enthusiasm for design was greatly enhanced with the ability to print these designs*

The fact that they are a trial kits and come with the instructional videos is a great way to test what tech works best for each school and how to use money wisely.

- *I loved it as my students were excited and engaged. I started to develop a deeper knowledge of STEM and it was fun!*

It was an excellent self-contained package. Instructions were clear and teaching units provided to get the instructional components up and running quickly. Minimum technological knowledge was needed and the videos provided any needed clarity.

- *Because this was a massive advantage to my classroom, extra-curricula activities and school community. Without this it is a very hard task to take on. Nobody will buy things they don't understand. It build knowledge and capabilities of staff and excites people. Pack-up was not easy, but the support around it and how to do it was outstanding. The team that supports the STEMShare process is outstanding.*
- *The kit was very well organised and the learning challenges were easy to follow. Our 7 students and 3 staff were able to make good use of the kit.*
- *It was great to have all the resources ready to go, so really I just had to become familiar myself and google to find different applications. Having the kit ready to go means we didn't have to invest monetary dollars but were able to gauge the effectiveness of the resource by observation of students and the applications we created for it.*
- *The resources are terrific as well as the library of lessons and activities which are so easy to access*

4. PRIMARY STUDENT SURVEY

The number of primary students who took the pre-survey at the beginning of Term 4 was remarkable and we collected 3247 responses from this cohort. However, an attrition rate of almost 50% occurred at the end of Term 4, with only1483 returning the post-survey. Although a total of 2701 primary students completed the post-survey, only 1483 had taken both surveys (i.e. pre and post) and hence, the rest of responses were discarded for data analysis. The breakdown of each gender and year groups is as follows:

Total Pre-test	Total Post-test	Year 4 Pre	Year 4 Post	Year 5 Pre	Year 5 Post	Year 6 Pre	Year 6 Post
N=3.247	N=1483	36.80%	38.30%	33.35%	35.13%	29.84%	26.57%

The items of primary students' pre and post surveys were almost the same, however, in addition to 14 items that measured 4 variables (i.e. Attitude, Interest, STEM Self-efficacy, and 21st Century skills) in both surveys, a few questions were added to the post-survey to capture students' perceptions of the STEMShare equipment. A four-point Likert-type scale was used in both surveys that ranged from 1 (strongly disagree=1 point) to 4 (strongly agree=4 points). Initially, the mean scores of each item in pre and post-surveys were compared with each other. As the means suggest (Table 7) improvement occurred in some items and the total mean score increased from pre to post surveys (Table 8).

	Total- Pre	Total-Post
Male	48.66%	48.62%
Female	51.34%	51.38%

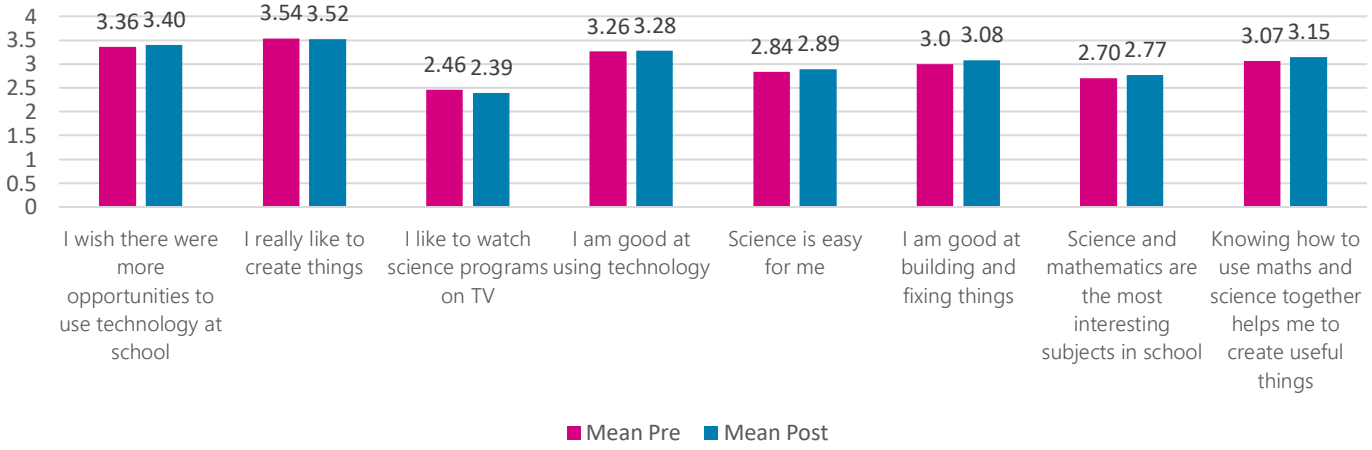


Table 7. Mean scores in pre and post surveys by item

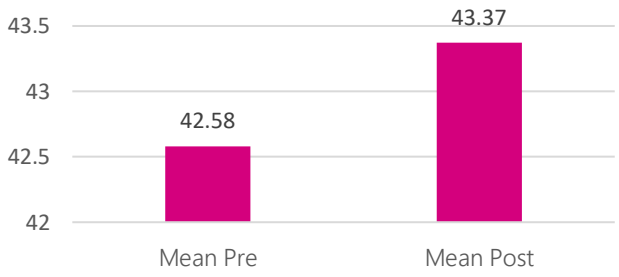


Table 8. Total mean scores in pre and post surveys

4.1. CHANGES IN MEAN SCORES OF VARIABLES

In the next stage of the analysis, items were categorized based on the variables they measured where interesting findings were observed. For instance, the lowest rating across the items of self-efficacy beliefs (M=2.84) was given to "science is easy for me" in the pre-test that suggested 73% agreed with the statement. This number increased to 75% (M=2.89) in the post-test. Also, other items of STEM self-efficacy beliefs (i.e. I am good at using technology and I am good at building and fixing things) increased from 89% and 75% to 91% and 80%, respectively. Items related to STEM attitude were rated moderately low in the pre-test; only 58% said science and mathematics were the most interesting subjects in school, suggesting students' somehow unfavourable attitudes

towards science and mathematics. Again, an increase from 58% to 60.62% was observed in the post-test in this item. Also, all the items of variable 4 (i.e. 21st century skills) considerably changed from pre to post-test, as shown in Table 9. For instance, 27% believed they were great at problem-solving in the pre-test, which increased to 32% in the post-survey.

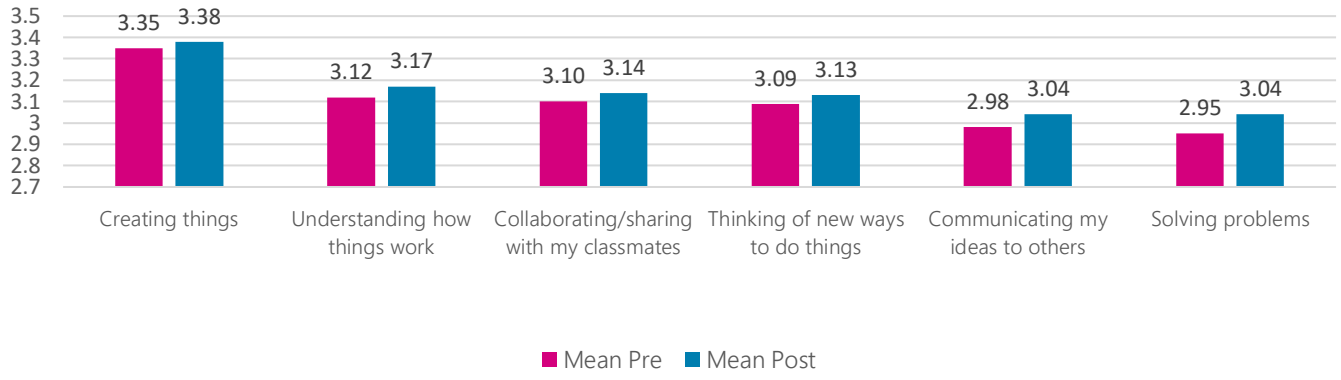


Table 9. Mean scores of variable 4 (21st Century skills) in pre and post surveys

As Table 10 shows, the mean scores of all the variables moderately increased from pre to post evaluation.

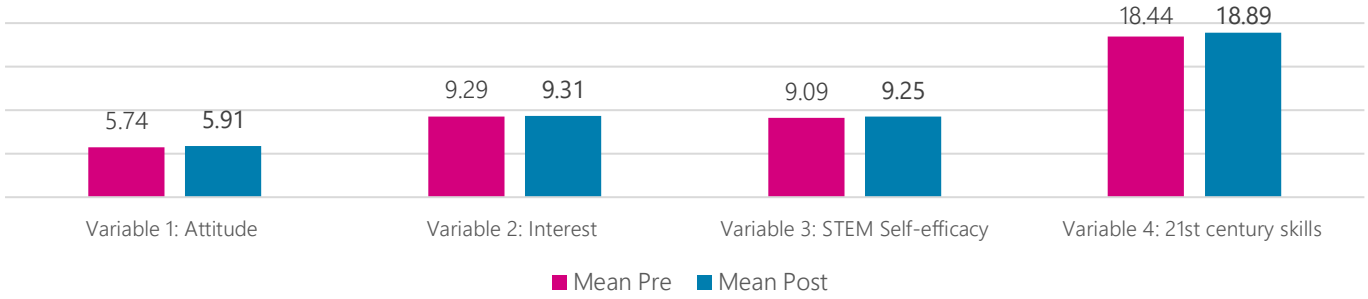


Table 10. Mean scores of each variable in pre and post surveys

4.2. PAIRED SAMPLES T-TEST

As discussed above, despite the increase in the mean scores of most variables, T-Test was required to understand if such increase from pre to post-test was a chance event or due to the positive impact of the project. It was further explained that the mean scores should reach a statistical significance (i.e. sig=00<0.05) to suggest the implementation has had a positive impact. Hence, initially, T-Test was run on the overall mean score of pre and post-surveys and the results indicated that the

		Mean	N	Std. Deviation
Pair 1	Sum-pre	42.5880	1483	6.75138
	Sum-post	43.3790	1483	6.63147

		t	df	Sig. (2-tailed)
Pair 1	Sum-pre – sum-post	-3.229	1482	.001

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

increase was statistically significant (Sig=0.001<0.05). In other words, there was an actual improvement in students' *overall* performance on the surveys from pre to

post evaluation, which was attributed to the substantial contribution of the program.

Another T-test was performed for each variable separately and it was found that the mean scores of three variables had a statistically significant change from pre to post-test, namely variable 1 (i.e. Attitude, sig=0.002<0.05), variable 3 (i.e. STEM Self-efficacy, sig=0.008< 0.05), and variable 4 (i.e. 21st Century Skills, sig=0.001< 0.05). More specifically, while a modest rise was observed in the mean scores of the 4 variables, the difference between the mean scores of variable 2 (i.e. Interest) in pre and post surveys was not statistically significant (sig=0.836> 0.05).

Based on this finding it was concluded that the project attained notable success in enhancing primary students' STEM attitude, self-efficacy and 21st century skills, however, it did not impact students' interest towards STEM. This was an interesting finding per se as the same observation was drawn from teachers' data. While teachers' STEM attitude and self-efficacy increased from pre to post evaluation, their interest remained unchanged. From the literature on STEM we know that enhanced attitudes and confidence contribute to an increase in STEM interest (Bell, Lewenstein, Shouse, & Feder, 2009). In other words, changes in attitudes and confidence seem to be easier to occur while it takes longer and extra effort to awaken students' and teachers' interest in STEM. This could have achieved through a greater access to STEMShare equipment because although the schools had the kit for one whole term, according to primary students, only 10% of them used the kits on a daily basis or more than 3 times a week (Table 11). It is assumed that a more intense engagement with the kits, would have enhanced the respondents' interest in STEM as well.

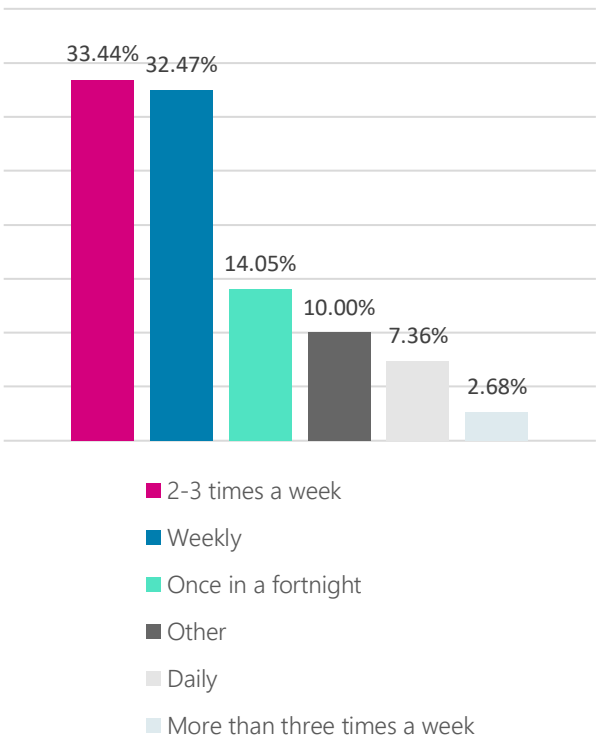


Table 11. Time frequency of kits usage by students

4.3. GENDER DIFFERENCES IN PRE AND POST SURVEYS

Research indicates that there is gender imbalance in STEM majors, with women being usually under-represented in STEM professions (Bøe, Henriksen, Lyons, & Schreiner, 2011). Also, differences have been identified in the persistence of students in STEM fields based on gender and ethnicity (Mau, 2003). It was decided to have a closer look at the performance of girls and boys separately in pre and post surveys to explore whether or not implementation of the project created any difference in the variables rated by each gender group. The first observation was that the total mean scores increased for both cohorts in the post-survey and such increase was statistically significant (Boys: sig=0.018<0.05 & Girls: sig=0.047<0.05).

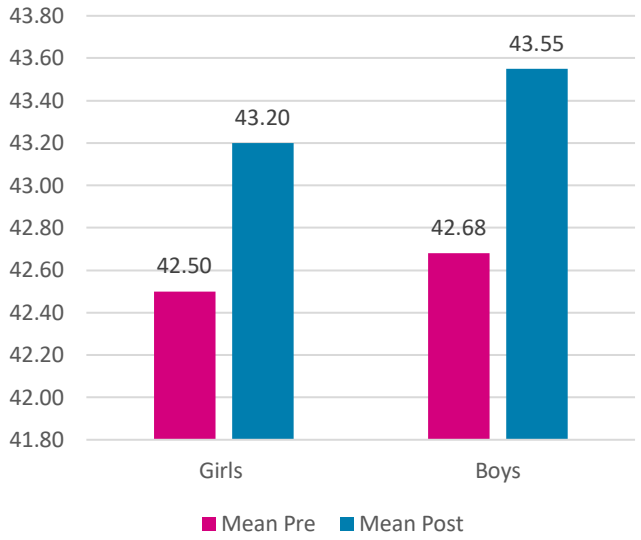
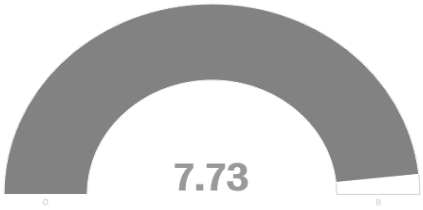


Table 12. Mean differences in pre and post surveys for boys and girls

A more interesting observation was girls' improvement on STEM self-efficacy beliefs. At the outset of Term 1, girls rated the items of self-efficacy moderately low (M=8.93) compared to boys (M=9.28). This finding confirmed previous research that showed girls had a lower STEM self-efficacy, especially during high school (Mangu, Lee, Middleton, Nelson, 2015). However, after the implementation of the STEMShare project, girls' mean score increased to 9.09 and the T-test suggested a statistically significant difference between pre and post mean scores on this variable for girls (sig=0.049<0.05). This was a highly positive outcome of the project as it confirmed having access to STEMShare equipment, even for one term, could make a difference in girls' STEM self-efficacy beliefs. Although boys' mean score for STEM self-efficacy increased from 9. 28 to 9.42 in the post test, T-test suggested that the difference between the means was by chance as the sig value was greater than 0.05 (sig=0.112>0.05). Another difference between the two cohorts emerged in Variable 1 (i.e. Attitude). The means increased on the post-survey for girls and boys similarly, however, only boys' mean scores had a statistically significant increase, meaning boys adopted a more favourable attitude towards STEM at the end of Term 4 while girls maintained the same attitude. The performance of the two groups was similar on the other two variables.

4.4. PRIMARY STUDENTS' RATING OF STEMSHARE KITS

Students were prompted to assign a number from 1 (very bad) to 10 (very good) to the kit they used. As the gauge chart below shows a rating of 7.73 suggested a solid majority of respondents had an overall favourable impression about the STEMShare equipment.



In addition to providing a rating, students were encouraged to reflect on their STEMShare experience by explaining their rating and discussing what they enjoyed the most about the kits. This part of the post-survey produced over 100 pages of commentaries, suggesting students' active engagement with the activity and their genuine enthusiasm for the kits and sharing their stories. According to students, not only were the kits "fun to use", "enjoyable", "very fascinating", and "interesting", but also they provided an opportunity for them to "go out of [their] comfort zone and create things', "learn maths and science", "challenge [themselves] to a new level", make [their] creativity even better", "experiment with different types of technology", and "communicate with others". Some examples are provided below:

- *It was an interesting to work with STEMShare kit, I learned a lot and it was nowhere to boring.*
- *It was really fun and exciting that is why I rated it at this number.*
- *I loved collaborating with my friends and because I got to learn coding.*

8/10 because solving problems while doing stem improves my collaboration skills.

- *A good opportunity to learn new things on technology.*
- *It helps your maths and since*
- *Because I like it a lot and would love to do it more and more but sometimes it can be a little*

stubborn and different to what I thought I programmed.

Using the STEM share kit has given me confidence to go out of my comfort zone and create things that wouldn't even come to mind.

- *Using the STEM share kit has improved my science and technology skills and proved to me that I can do things that I never thought I would do. I truly believe that this program should continue.*
- *Because I enjoyed my time learning how to use the STEMShare Kit but I didn't really understand it for a while.*
- *Because it is interesting fun*
- *Because it is fun building and making things*
- *Because I can do it with friends easily and when I do it, it helps me with what I don't know and I'll get to know it.*
- *The kit was really fun and interactive and I would definitely do it again.*
- *Because I love that we had gotten the chance to do this at this age and I got to use different resources and to work different muscles in the brain.*
- *I gave it a nine because it gave me an opportunity to use different brain muscles*
- *I enjoyed having a range of technology to try and figure out what you like best.*

Because it has helped me explore a world of technology.

- *I enjoyed being able to experiment with different types of technology*
- *Because the dash bots were super fun to use which made me interested in technology*
- *Because it has got me interested in stem.*

Although the comments were mainly favourable, there were a number of students who tended to be slightly critical and cited reasons such as not having the chance to use the kits, problems with the apps, poor login in and connections, and being confused or simply bored, for their dissatisfaction:

- *Cause I don't really know how to use it*
- *Sometimes it is annoying to use because the coding doesn't work*
- *We didn't get to use it all the time*
- *Because I really liked using it but on some days I got bored.*
- *Because it wasn't that good because I didn't really get to use it*
- *We couldn't connect to co spaces and there weren't many apps to go on.*
- *It was fun but had poor login in and connections sometimes.*
- *I am not sure some of the apps aren't really that good and most don't work*
- *I liked using the VR but you could never go onto the CO spaces because I don't really know I think it was the wifi so you guys should probably get that fixed.*
- *Because I didn't get a good enough chance to learn how to use all the technology*
- *I don't think that they have organized the pieces of Lego in the box so that it's hard to lose. On the first couple of days that we had the box we lost so many pieces of Lego! Everyone in our class tried to keep them contained but the bad packaging made it so easy to lose them. It was way to expensive and what we got in return I thought was way under-rated.*
- *I have not used them much to give it an amazing rating.*
- *Because its kind of confusing*
- *Because it didn't work smoothly and it is so boring*

4.5. STEMSHARE KITS' CONTRIBUTIONS TO STUDENT LEARNING

One of the main issues that students passionately discussed was the benefit of using the STEMShare equipment and its contribution to their personal and intellectual growth including improvement to their creativity, learning, teamwork, and use of technology:

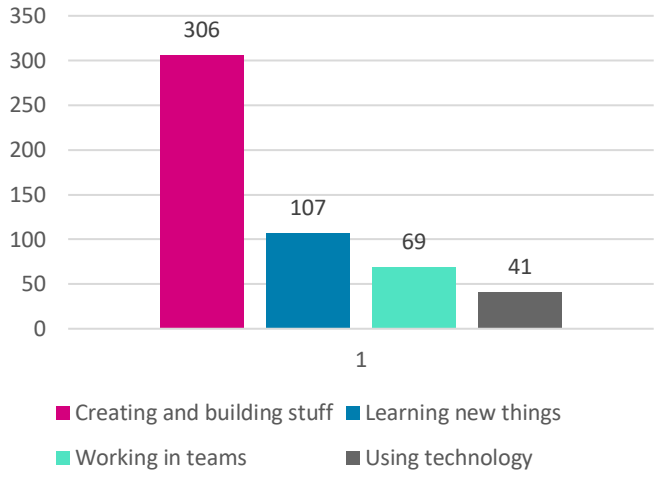


Table 13. STEMShare kits' contributions to student learning

1.1.1. CREATING AND BUILDING STUFF

The most frequently mentioned benefit was having the opportunity to get creative and build new things. A large number of students were amazed at how technology helped them create "3D objects", "a world", "animals", "buildings", etc.

- *Creating all sorts of amazing creations then printing them with plenty of cheer and laughter with lots of friends.*
- *Creating my own world on vr*
- *Creating and designing my environment.*
- *You get to be creative of what you do.*
- *How we got to create a story*
- *Creating new things*
- *That you could build things and see other peoples creations and code what u build.*

The thing I enjoyed the most about this kit is the coding and the mindset you are put in when creating such wonderful things, I would have never thought that what I have created with this kit was even possible to make.

- *Creating the building*
- *That you can make anything your heart desires*
- *You can make and create whatever you want*
- *I could create 3d objects*
- *Using the ozobots because you could create a trail in which the ozobot had to follow.*
- *The chance to be creative.*
- *Getting to create a world and seeing it in 3D*
- *What I enjoyed the most was creating your own thing and using the VR goggles.*
- *learning how to make animals and creating things and watching it getting made*

I enjoyed using the Lego WeDo 2.0 most because I like to create things and that will be useful because I do think about being some kind of engineer in the future.

- *Creating things that we can actually use*

1.1.2. LEARNING SOMETHING NEW

Many students emphasized that the learning that occurred throughout the STEMShare journey was the best part and some of them elaborated on what they learnt specifically:

- *Because it is fun and helps me with learning.*
- *Learning about the green screen and how it works, the special effects were awesome too, and also the right balance, position, temperament and brightness. Using the STEMShare kit was brilliant. (thank you!!!!!!!)*
- *I had a lot of fun using the stem kits I have learnt a lot of things. I wish we can use the stem kits again sometime.*
- *I enjoyed using the blue bots the most because you get to learn how to control something of your own*
- *We got to learn new things*
- *Learning new things that I didn't know about.*
- *Because you learnt a lot more about technology*
- *How fun it was and how you were learning while doing it*
- *Going on co space and learn new things.*
- *It has made me learn more about technology.*
- *You learn how to do more things*
- *Building the robots and learning how to code it.*
- *It helps you learn*
- *That I could have fun and learn how to print things from corn starch.*

It was a good and different way to learn science and robots

- *It helped me learn new ways to do different things in the school*
- *You can learn to code and because it is satisfying to watch.*
- *It is fun learning about tech and science*
- *I enjoyed that I got to learn what to do on a vr headset and I enjoyed making the thing on co spaces*
- *I enjoyed the most learning new things and using the VR kit it was so much fun.*
- *Looking at the amazing places around the world and learning more about science, engineering and all that kind of stuff that includes science.*

1.1.3. WORKING IN TEAMS/WITH FRIENDS

Another key benefit of the kits was how they helped with teamwork and collaboration as students were expected to help their teammates, cooperate and communicate.

- *I enjoyed the collaboration, and teamwork that is put into all of this.*
- *I loved having to work in a team and everybody helping each other out when you are stuck.*

That you try new things out and work as a team with all your friends.

- *The teamwork. The teamwork helped us to cooperate better.*
- *Yes I enjoy the STEMShare kit and it help me talk to my teammates*
- *All the team work*
- *We work as a team and help each other*
- *The coding was the most enjoyable part for me but it needed teamwork for it to work properly which I thought was fantastic!*
- *That we got to do to team work*
- *I liked working together as a team in the progress of making all the movies we did.*
- *You got to work as a team and have fun with others*
- *I like that we worked collaboratively*
- *Collaborate and share ideas*
- *Enjoyed working with my friends*
- *I enjoyed working with friends and co-operating well.*
- *I enjoyed being with my friends*
- *I enjoyed being able to make cool things with my friends.*

The thing I most enjoyed about it was how it was fun and it helped me make friends.

- *You could do it with friends*
- *I enjoyed working with my friends and being able to communicate in something other than lunch talk. in the end we ended up naming our robot Monte-Carlo*
- *I most enjoyed working with my friends and having fun*
- *Being with my friends and learning new things*
- *Working with people I never work with*
- *I enjoyed the group work were everyone had lots of fun and enjoyed them self.*
- *Because it was fun working in groups and trying to make stuff and work together with my class.*
- *Working in a group with good friends*
- *I like how you can interact with your peers*

1.1.4. USING TECHNOLOGY

Not all students had the chance to use cutting-edge technology on a regular basis so these students loved exploring the possibilities the technology offered and they learnt that technology was not just "YouTube and Netflix":

- *I enjoyed the use of technology because we don't usually use technology like this.*
- *The technology and science part because to me I quite enjoy these subjects.*
- *I enjoyed the use of technology for many different things.*
- *The games and technology.*
- *How to use technology.*
- *The fact that we get to work with technology.*
- *I get out of class and it taught me a little bit more about technology.*
- *Because you learnt a lot more about technology.*
- *How cool the technology is.*
- *I got to explore the new technology.*

I learnt that the best thing is technology and hope I become a technology person that creates technology to help lives.

- *Technology is much more fun than I thought it was before we used the kits.*
- *Learning that technology is not just for YouTube Netflix and Instagram and musically and Snapchat*
- *That this technology could help us in the future because of these world problems such as littering or pollution.*

5. CONCLUDING REMARKS

This research was conducted in an attempt to document the extent of the impact of the STEMShare Community Project on primary students and teachers in Term 4. Three research questions were raised and the data collected through surveys was subjected to statistical analysis to answer these questions. In total, 255 schools responded to the surveys sent out at the beginning and end of Term 4.

The findings demonstrated that the project created discernible impact on primary students (4-6) and teachers by improving their STEM self-efficacy beliefs and attitude, in particular.

The NPS for teachers was 75.1, which was overwhelmingly positive and indicated that 79% of teachers were promotors of STEMShare Community project. It is worth noting that the number of teachers promoting the project increased by 10% from Term 3 to Term 4, confirming considerable improvement made to the project. The project also scored a top rating among primary students (i.e. 7.73 out of 10) and a vast majority of students agreed that they enjoyed working with the STEMShare kits and could appreciate their benefits. To provide a more comprehensive account of the effectiveness of the STEMShare Community project, the research questions raised in the introduction of this paper are answered separately in the following section.

RESEARCH QUESTION 1:

❖ *To what extent did teachers' and students' STEM self-efficacy, interest and attitudes change from baseline to follow-up?*

The data collected from primary students suggested that there was a positive shift in 3 variables form before to after the implementation of the STEMShare Community project, namely STEM Attitude (Mean Pre = 5.74; Mean Post = 5.91), STEM Self-efficacy beliefs (Mean Pre = 9.0; Mean Post = 9.25), and 21st Century skills (Mean Pre =18.44; Mean Post = 18.89). Such increase in these variables was found to be statistically significant, which suggested the STEMShare Community Project had a positive impact on primary students' STEM attitude, self-efficacy beliefs and 21st century skills.

This finding confirmed previous research that showed engaging students in STEM activities that are fun, hands-on and linked to everyday contexts creates exciting and motivating learning experiences, enhance their attitudes towards STEM, and in the long run encourage them to pursue STEM careers (Hollenbeck, R., & Fey, J., 2009; Koszalka, Wu, & Davidson, 2007).

Teachers also improved on 2 variables; STEM Self-efficacy (Mean Pre = 29.55; Mean Post = 33.05) and Attitude (Mean Pre = 17.89; Mean Post = 18.29) while these gains were statistically significant. In fact, teachers had the greatest increase, among all variables, in STEM self-efficacy beliefs, which again highlighted the effectiveness of the PL. In other words, the effective PL enabled teachers to acquire a greater sense of STEM competence and confidence, as also observed by other researchers (Kamalodeen, Figaro-Henry, Ramsawak-Jodha, & Dedovets, 2017). An obvious example of such improvement was teachers' assessment of their own knowledge of teaching STEM that increased from 46% (Mean= 3.27) to 70% (Mean=3.75) at the end of Term 4. Despite the positive influence of the project on the above-mentioned variables, 1 variable (i.e. Interest) remained unchanged from pre to post evaluation for primary students and teachers. In other words, the

implementation did not enhance the participants' STEM interest by the end of Term 4. This was unfortunate but not unexpected because there are studies that show STEM education does not have any positive impact on increasing students' interest and motivation (Yildirim, 2016). However, the bulk of research on STEM education suggest that by increasing student exposure to STEM activities and disciplines they become more interested in STEM and more likely to major in STEM fields (Wang, 2013). In this research, it was found that, only 10% of primary students used the STEMShare kits on a daily basis or more than 3 times a week, hence, a greater involvement in the project could have enhanced its positive impact.

RESEARCH QUESTION 2:

- *Was there any statistically significant difference between girls' and boys' mean scores for the measured variables?*

Differences by gender were found in primary student data only for 2 variables (i.e. STEM Self-efficacy beliefs and Attitude). More specifically, the results suggested that girls had a higher feelings of self-efficacy by the end of Term 4 and their mean scores increased from 8.93 to 9.09. A primary implication of this finding is that teachers must be increasingly mindful that girls tend to second-guess their STEM abilities and take a back-seat to STEM fields.

By implementing tailor-made STEM activities for girls teachers can further enhance their STEM self-efficacy and excite their interest. Another gender difference was found in boys' ratings of STEM attitude where they outperformed girls and the means gained statistical significance on this variable.

RESEARCH QUESTION 3:

- *To what extent was the STEMShare professional learning effective in upskilling teachers' STEM teaching and learning?*

Overall, 85% of teachers were satisfied with their PL experience and 93% agreed that "Resources and Learning materials" were the most useful component of the PL.

A comparison between the mean scores of PL subscales (8 items) in Terms 3 and 4 revealed that Term 4 teachers rated 7 items of this question higher than Term 3 teachers, suggesting a tangible improvement in different aspects of the STEMShare PL program. For instance, "collaboration between teachers from different schools" increased from M= 2.84 in Term 3 to M= 2.91 in Term 4, predominantly a result of teachers' more active engagement with social media. This argument was further confirmed by the high ratings given to social media that suggested teachers' deep appreciation for the key role of social media in creating a collaborative online environment, a community of practice, where they could have easy access to resources, pose questions, present their challenges, discuss teaching strategies, and provide support to each other throughout this journey. However, teachers identified challenges such as time constrains and technical issues that tended to persist from before to after the project. Although providing equipment, technology support and PL programs is key in program implementation, the role of school administration in STEM projects cannot be overemphasized. More opportunities and roles for school administrators can be created to increase their familiarity and involvement with STEM education (Al Salami, Makela, & de Miranda, 2017) to be better able to address the challenges teachers might face throughout their STEMShare journey.

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