# IVR as a tool to create digital art: The case study of Blacktown Girls High School's engagement with stem.T4L

Through the lens of a case study on Blacktown Girls High School, we looked at girls' engagement with stem.T4L Immersive Virtual Reality kit implemented in an after school art Masterclass. In this report, we tell stories of determination, problem-solving, collaborative group work, and self-directed learning enhanced by students' access to IVR technology.

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# EXECUTIVE SUMMARY

The factors responsible for women's disengagement from STEM fields are both intrinsic and extrinsic. At one end of the spectrum is low self-confidence and lack of interest (intrinsic factors). At the other end, there are contextual factors such as limited exposure to and awareness of STEM fields and careers (extrinsic factors). In an effort to transcend contextual limitations, the education system worldwide has strived to establish learning environments conducive to higher participation of girls in STEM over the last few years. Here at stem.T4L, where a strong focus is placed on raising students' familiarity with and effectiveness in the use of technology, we continue to examine the potential of stem.T4L on girls' learning and engagement. In the present research, we endeavoured to unpack whether an after-school art Masterclass learning environment equipped with stem.T4L IVR kit would enhance girls' understanding of the affordances of IVR for creating digital art, and hence heighten their interest and confidence in using technology.

Blacktown Girls High school served as our case study, where we collected extensive data through pre-post surveys, focus group interviews with students and teachers, and classroom observations. Students' learning journeys were documented throughout the four school terms in 2020, with a temporary halt in Term 2 due to school closure caused by the COVID-19 pandemic. Implementing a project-based approach, the Masterclass teachers orchestrated learning activities that prepared students for a journey to create a digital artwork, called the Relaxation House. At the outset of the course, students who participated in the focus group interview appeared confident and highly interested in harnessing IVR for creating art. Their prior positive experiences of learning with technology (e.g. VR, robotics) had sparked their curiosity to further explore the potential of IVR. The baseline survey data (N= 23) confirmed this observation further where we found that girls' confidence with using technology was noticeably high. Their interest in learning about technology was also exceptional, with 100% indicating that they would like to know something about how technology works.

The Masterclass participants received 15 lessons throughout the year and completed the course with an outcome as significant as designing a digital environment, which could provide a virtual experience to the user as well as serve as a relaxation activity.

Apart from the course being an artistic success, the Masterclass with IVR resulted in a number of positive outcomes that are outlined below:

- Upon completion of the Masterclass, students reported having a deeper understanding of the role and importance of technology. For 69% (N=9) of the pre-survey respondents, technology meant "devices" or "anything digital", with little attention being placed on the far-reaching impacts of technology. This figure dropped to 46% in the post-survey. In other words, five students adopted a more 'holistic view' by the end of the course; they moved away from perceiving technology simply as "devices and phones" to developing a wider awareness around technology, defined by one student as "the application of science in human life".

- Gain in students' knowledge and aspiration for technology career pathways was another key by-product of the course. Through the real-world application of IVR, students learned to appreciate the various possibilities that technology offered for creating art, which in turn opened up new horizons for them, motivating them to consider career options in the field of technology.

- Student engagement was a conspicuous feature of the Masterclass. The high frequency of on-task behaviour (behavioural engagement), contributions to group work (social engagement), planning and role allocation (cognitive engagement), and application of

technological knowledge in new situations (conceptual-to-consequential engagement) were credible evidences to suggest that all students were consistently engaged in the activities.

- The main source of self-efficacy is believed to originate from the direct experience of mastering a task. This is confirmed by the present research which revealed that students' success in creating the Relaxation House (i.e. Mastery experience) bred a notable sense of confidence. All interview participants pointed out that they had felt a boost in their confidence, rooted in self-belief that they had succeeded in using IVR to create digital art.

- The Masterclass learning environment created ample problem-solving scenarios for participants where they learned how to (1) define a problem (i.e. how to create a tangible product within the IVR environment); (2) generate ideas on how to approach the problem; (3) adopt technical and creative solutions; (4) tinker with a range of software applications and tools to modify and enhance the selected solutions; and (5) solve a real-world problem.

- We observed behaviours and attitudes that indicated students were able to regulate their own learning and were in charge of the learning process. For instance, they collaboratively defined goals for their group, assigned roles to each member, and came up with a timeframe to achieve the desired outcomes. We postulate the Masterclass teachers' "guide on the side" approach contributed significantly to students' autonomy and enabled them to become self-directed learners.

- The stem.T4L environment lent itself perfectly to many situations that required students to step outside of the box, embrace new ideas, become decision makers, and express their creative freedom in innovative ways.

- The hands-on and experiential learning with IVR paved the way for on-going collaboration and teamwork, bringing together students from different year groups with different skills and strengths to collaborate, share ideas, and learn from each other.

- stem.T4L IVR kit, while utilised in a specific extra-curricular context of the art Masterclass in Blacktown Girls High school, resulted in the achievement of wider curriculum and syllabus outcomes for students. Students who participated in the Masterclass demonstrated technical accomplishment, used a range of materials, techniques, and process to create art (Visual Arts syllabus outcomes), and made informed choices to develop and extend concepts and different meanings in their artwork (Photographic and Digital Media syllabus outcomes), to name a few. The art Masterclass also generated tangible digital literacy outcomes that are a key aspect of contemporary STEM agendas in schools across NSW. As such, we postulate that stem.T4L IVR equipment once fully integrated, has the potential to enhance student learning outcomes across a wide range of STEM and non-STEM Learning Areas.

The findings of the present research demonstrated that using IVR for creating digital art is a promising approach to stir up girls' interest in technology, enhance their engagement in learning, raise their awareness of the affordances of digital technology, and motivate them to further explore career options in the field of technology.

# INTRODUCTION

> "IVR has become a very possible future for me... because I know how to use it now. I'm starting to think of the possibilities and how far I can take it into the world, and how I can share this experience with other people."
>
> - Ann, art Masterclass participant, final focus group interview.

International research on STEM frequently highlights a gender gap that starts to widen as early as high school. That is to say, although their aptitude for success in STEM is similar, boys' and girls' interest, self-efficacy, and persistence in STEM fields differ dramatically (Cooper, & Heaverlo, 2013; Else-Quest, Hyde, & Linn, 2010). For instance, international researchers found that male students had higher self-efficacy and outcome expectations in STEM related classes compared to their female counterparts (Falco & Summers, 2017). Other studies have observed that males' interest in STEM careers remained stable throughout high school, whereas for females it declined from 15.7 to 12.7 (Sadler, Sonnert, Hazari, & Tai, 2012). Another interesting study was conducted on the same group of girls at three different time frames. The findings revealed that 30% of girls in middle school (ages 11-14) believed coding and programming required for some jobs, were not for them. In high school (ages 15-18) the figure jumped to 40%, and by the time they were in college, 58% counted themselves out of those jobs (Kesar, 2017). The findings from these studies, amongst many more, indicate that the underrepresentation of women in STEM careers originates from a loss of interest, which occurs approximately at age 11 as some researchers believe (e.g. Stoeger et al., 2013), and exacerbated by their lack of self-confidence in STEM.

The factors responsible for women's disengagement from STEM fields are not just intrinsic, but a number of contextual and extrinsic factors contribute to this "leaky pipeline" (Blickenstaff, 2005). For instance, lack of family/teacher/peer support (Aschbacher, Li, & Roth, 2010), cultural stereotypes about "who" should pursue STEM (Schuster & Martiny, 2017; Smeding, 2012; Zhao, Carini, & Kuh, 2005), and absence of female role models and mentors (Cheryan, Master, & Meltzoff, 2015), are three main underlying causes for women's limited participation in STEM.

To address 'pipeline' issues and attract girls and women to STEM subjects, varied programs and activities have been designed and introduced. If successful, such interventions are likely to make STEM appealing to all girls, not just those already interested in these subjects (Chun & Harris, 2011). That is because when girls are exposed to real-world STEM scenarios, where they see the multiple applications of STEM, they come to view careers in these fields as desirable. Particularly for women, who are motivated by work that can have positive impacts on the world (Modi, Schoenberg, & Salmond, 2012), technology's transformative potential creates new career aspirations (Kesar, 2017). Hence, STEM programs that engage girls in hands-on collaborative activities and focus on real-world issues, are likely to improve their perceptions of their abilities in STEM, heighten their motivation, and encourage their participation in STEM fields (STEM Task Force, 2014).

Although STEM programs take various forms, one approach that is believed to increase girls' engagement with STEM in particular is STEAM (Wajngurt & Sloan, 2019). STEAM is a student-centric approach that adds the arts component to the STEM subjects to enhance students' creativity, innovation, and problem-solving skills (Root-Bernstein, 2015). A STEAM curriculum provides a fresh lens through which students can see how technology is used for 21st century artistic purposes (Liao, Motter, & Patton, 2016). Moreover, as STEAM adds social and human aspects to the STEM domain, it appeals to all learners including those that are not STEM inclined (Ahn & Kwon, 2013).

STEM/STEAM programs have been implemented in different contexts as a catalyst for generating interest and engagement in STEM. In Australia, where women account for only 16% of the STEM-skilled workforce (Australian Academy of Science, 2019), there is a dire need for creating environments conducive to enhanced STEM interest and aspirations amongst girls. STEM participation gaps are even greater for women from low socio-economic status backgrounds and Aboriginal and Torres Strait Islander communities, putting them at "high risk" of not

developing STEM skills and capabilities (Australian Education Council, 2015). In response to the call for greater "national effort" to increase female STEM participation and attainment (Australian Education Council, 2015), a range of girls-only STEM initiatives have been introduced in Australia in the last couple of years. For instance, STEAMpunk Girls Program (Ng & Fergusson, 2020), funded by the Australian Government, aimed at increasing high school girls' STEM learning experiences and engagement. The positive outcomes of the program suggested an increase in girls' confidence and motivation as well as their knowledge and aspirations around STEM fields and careers.

Stem.T4L is another large-scale initiative by the NSW Department of Education. Through provision of STEM gender neutral technology such as PC Robotics, Immersive Virtual Reality (IVR), and Filming kits, stem.T4L endeavours to engender STEM enthusiasm, confidence, and knowledge not only amongst girls but all students and teachers alike across NSW. The hands-on STEM learning experiences created by the stem.T4L technology, have promoted active engagement with STEM in 1,812 schools so far, and boosted students' and teachers' confidence in using technology for learning. The extensive research conducted over the course of the project is available at: https://t4l.schools.nsw.gov.au/stemt4l/stem-t4l-research.html

In some of the earlier studies on the stem.T4L project, we investigated girls' engagement with stem.T4L technology in co-education contexts. In this study, we look at a girls-only school that implemented one of the stem.T4L kits in their STEAM extra-curricular course to explore:

1. how this particular setting lends itself to an increased integration of the stem.T4L equipment,
2. how girls' understanding of, and interest in STEM pathways and careers are shaped by their new-found knowledge of STEM technology and affordances, and
3. what girls' key takeaways are from this experience.

The following section provides an overview of Blacktown Girls High school, as a case study for this research. We present data collected from the art Masterclass, that utilised the stem.T4L IVR Kit over four terms in 2020. We will then discuss the findings to determine whether the stem.T4L technology has the potential to positively impact the learning environment to create higher engagement and motivation amongst girls, and hence spark their interest in STEM-related fields.

# BLACKTOWN GIRLS: A CASE STUDY

## An overview on Blacktown Girls High school and the art Masterclass

Located in Western Sydney, Blacktown Girls is a government high school, enrolling students from different academic backgrounds including selective and local comprehensive contexts. 86% of students speak a language other than English and a large number of students come from refugee backgrounds[1]. For over ten years, Blacktown Girls has run art Masterclass programs as an extra-curricular course held after school hours. Participation in the Masterclass does not require any prior knowledge and the selection of students is solely on a first-come first-served basis, although the number of students taken in each year is limited to 25. At the beginning of the year, the art teachers circulate a school-wide notice to give all students the opportunity to participate, provided they obtain their parents' consent.

The aims and art-making activities of the Masterclass vary each year and they are usually different from what students normally do in their art class. For instance, in 2019, Blacktown Girls collaborated with a few street artists and Blacktown Hospital to help design a mural. In 2020, the implementation of stem.T4L gave the art teachers of Blacktown Girls the opportunity to integrate STEM technology in their Masterclass. The stem.T4L kit that the school had booked was IVR. Designed specifically for

*1 The information provided on Blacktown Girls High school was obtained from Myschool website:*
https://www.myschool.edu.au/school/41808

secondary students, IVR taps into multimedia and design thinking to make STEM/STEAM learning more engaging by encouraging creativity, problem-solving and innovation.

The art Masterclass met each Tuesday afternoon, from Week 5, Term 1 to Week 8, Term 4. In total, students received 15 lessons throughout the year, with a poster presentation in the final session concluding their journey.

Early in Term 1, the research team met up with the 23 students, who had signed up for the course and had consented to participate in the study, and provided details on the research, which included participation in a survey and focus group interview before and after completion of the course.

Additionally, classroom observations were designed to be conducted at the outset of the course to document students' initial impression and engagement with the IVR technology, with further observations scheduled for the year ahead. However, as schools had to switch to an online learning mode following the COVID-19 lockdown, classroom observations came to a halt and only two observations were completed throughout the year. Apart from the data collected from students, a one-off focus group interview was held with the two art teachers (Ms Kataria & Ms Gifford) at the conclusion of the course. The teachers were also invited to share their lesson plans, classroom activities, and students' work samples with the research team to help them obtain a clear understanding of varied learning stages students were going through and the development of their artwork. Table 1 presents the data collected from the research participants (i.e. students and teachers) at two intervals:

| | Baseline | Follow-up |
|---|---|---|
| **Student Survey** | Number of responses: 23<br><br>Year 7: N=10<br>Year 8: N=8<br>Year 9: N=2<br>Year 10: N=3<br><br>March 2020, Term 1 | Number of responses: 13<br><br>Year 7: N=4<br>Year 8: N=5<br>Year 9: N=1<br>Year 10: N=3<br><br>December 2020, Term 4 |
| **Student Focus group interview** | Participants: 7<br><br>March 2020, Term 1 | Participants: 9<br><br>November 2020, Term 4 |
| **Classroom observation** | Students observed: 21<br><br>March 2020, Term 1 | Students observed: 18<br><br>August 2020, Term 3 |
| **Teacher interview** | N/A | Participants: Two<br><br>December 2020, Term 4 |

*Table 1: Data collected across the baseline and follow-up phases*

## Who are Blacktown Girls? Data from baseline focus group interview

The first focus group interview with students, held early in March 2020, served specific purposes including generating baseline data on their familiarity with IVR technology, their prior experiences and perceived confidence with technology, the skills and knowledge they were hoping to develop through the Masterclass, and any learning concerns or challenges they had or could foresee.

The seven students who participated in the 30-minute interview, conveyed a high-level of confidence and enthusiasm for working with technology, in general, and venturing on the new adventure of utilizing IVR for creating art. What had contributed to their self-perceived confidence in using technology appeared to be their everyday use of computer devices to access online resources and to complete learning activities and homework. As they told us, they were confident that they could easily transfer the skills they had acquired before, such as troubleshooting, to

any new situation, and implement the same skillsets when working with IVR, as indicated in the examples below:

Mina: "*We always use our laptops for doing normal tasks, which makes everyone basically able to use IVR, so you're really confident using IVR because you've used technology before*[2]".

Sofia: "*Once you get to use technology, you can access a wide variety of resources that can help you understand something better or something new*".

Another driving force behind students' confidence in their abilities to harness new technology was the school's strong push towards implementing new technology to improve their students' digital capabilities. The school borrowing the stem.T4L equipment was an indication of its high regard for adopting emerging technology in education; something that participants appreciated and highly valued:

Eva[3]: "*The school really respects technology and they always push us further, and that's why they decided to bring the VR in because it's going to help us get our creative minds on and that's why we have them*".

Kate: "*As someone said earlier, we always used technology in our day-to-day life, because if we really want to learn about it, we should use it, so they [school] brought it so we could learn more about it*".

Ann: "*Technology is getting more advanced, so they [school] also want to teach us how to use new technology as well, so we get used to it as we go on. And also, our career might involve that particular technology as well*".

The interview with the students further revealed that they had background knowledge and some experience with VR either outside of school, or in their history lessons. So, they all had a sound understanding of the affordances that VR would present, especially the unique learning opportunities it could create in their art unit.

For example, Kate said: "*It [VR] lets you explore new techniques. Rather than just draw it on a piece of paper, you could actually recreate the thing as though you were part of it*".

Mina agreed and added: "*On pencil and paper, you can't really be inside – you can't really be with the picture. You can't really see its true thing. And then if you're in virtual reality, it can be interactive, and you can see new perspectives of it*".

Clearly, the VR world was not entirely new to these students, where their prior positive experiences had triggered further curiosity for exploring the IVR kit, particularly for coding and programming within the IVR environment. Although coding was a familiar concept and they had gained some knowledge of coding in primary school, a few participants were keen to know what creating an immersive experience with IVR technology entailed and how coding was implemented in IVR. For example, Sofia said: "*In primary school, there was this robotics – you had to come early in the morning, and then do robotics. I was in that group. And we learnt how to do coding in Year 3 and stuff like that, but IVR is kind of different... because you have to make an experience for people*".

Kate expressed a similar view; she was ready to explore IVR technology further and unlock its potentials for programming: "*I've watched IVR before on the headset, but I haven't really programmed something on the headset*".

Having the opportunity to work with VR technology, had given the students insights in to key capabilities for effective teamwork. For instance, Maryam and Sofia pointed out that it was crucial to never give up and show resilience to achieve outcomes:

Maryam: "*Sometimes, when you get really frustrated because you've tried so many times and it's not working, so then you just give up in that moment. But I usually try not to, and I just try and ask for help*".

Sofia: "*I feel that everyone wants to give up sometimes, but when you're doing something, you shouldn't really ever give up on anything, because then you're never going to be able to learn it and you're not going to be able to do anything*".

Kate agreed and shared her own experience of using VR to conclude how "*trial and error*" was an integral

2 *Italics is used to denote the text is a direct quote from the participants.*
3 *Pseudonyms are used for the students to protect their identity.*

part of using VR technology, and everyone should be willing to test ideas out, learn from them, and apply their learning to a new context:

Kate: "*With the VR, it's almost a constant process of trial and error. So, you can try different methods every time and even if it might not work, you can always use that method for a different idea that you might come up with along the process*".

Ann shared her sentiments and warned that [if you stopped trying], "*then you're never going to be able to learn it and you're not going to be able to do anything*".

Other skills that students agreed their team should possess included planning, collaboration, and cooperation. For Mina, the key to success when designing a project, was to map out every step of the way and stick to the roadmap. She said: "*You can't just get on a computer and start. You have to plan it out; how your game will be, the rules, the time limit, or how are you going to make it*". Sofia stressed the importance of cooperation; respecting everyone's voices even when they do not echo your ideas, and giving others the chance to have an input: "*You also have to use the skill of cooperation because it's not always everyone's going to agree with you. There's always going to be some disagreements with each other*".

Most of the students were also ready to take on any challenge that could arise throughout the learning process and were confident that they were able to resolve any issues through seeking help and maintaining perseverance. For instance, Mina said:

"*Usually, when I have a challenge, I'll, ask my friends if they can help me out because you're not the only person out there. There's people to help you as well. And, sometimes, they're bigger – more knowledge of something that you might not really know (sic). And I might ask the teacher as well because they're always there to help you*".

Similarly, Sofia explained how she would stick around and keep exploring until she found the answer: "*If there's a challenge, you can try and find why, how, and if something is not working, you can give some time to explore just around and see what each tool is for and what it does*".

The last question addressed in the focus group interview aimed to examine girls' personal beliefs about STEM gender stereotypes and their appraisal of their abilities to succeed in STEM fields. Literature in this realm suggests that one of the key barriers to girls' engagement in STEM is the masculine connection to STEM (Smeding, 2012), and the extent to which they support STEM stereotypes, which seem to become embedded in girls' and boys' mind around the age of 15 (Steffen & Jelenec, 2011). Interestingly, students participating in the interview adamantly opposed to such theories, evident in their protest that anyone could do STEM as long as they "*put their mind to it*". They regarded interest and perseverance as factors determining one's success in STEM rather than gendered categorisations. The quotes below sum up the lively discussion that this interview question prompted amongst the students.

Maryam: "*It's not so much about the gender, but if you have the interest for it, there isn't really anything stopping you*".

Kate: "*I think especially in today's society, there's no restrictions for girls, it's not like boys can only do this and girls can only specifically do that. Anyone can do anything*".

Ann: "*It doesn't really matter because anybody can do anything if they just put their mind to it*".

Eva: "*I think that the person who made Instagram is actually a woman which means technology is for both genders, and women are currently discriminated against in the field of technology*".

Olivia: "*I actually know someone that is a scientist and she's a girl. And she's very good at that field of study. I also know a boy who's a scientist. And they're both very good, so that just tells me that people can be anything they want to be and just because there's stereotypes, it doesn't mean you have to go by those stereotypes*".

The data derived from the preliminary focus group interview, as described above, proved illuminating and offered valuable background information on research participants. What we observed was a strong passion for art, high confidence in using technology, and keen interest in learning how IVR equipment could be applied in the art world. This

observation echoed previous studies on STEM extra-curricular courses that suggest as these activities are "self-selected", students who choose to participate are often those with a deep interest and curiosity about the subject (Dyer, 2004). Without a doubt the Masterclass participants were extremely motivated and ready to embark on this new adventure. What confirmed this conclusion further was the baseline student survey, run in parallel with the focus group (i.e. March 2020). The student survey was designed to measure girls' self-perceived confidence in technology, their attitude towards use of technology for learning, their interest and aspirations for STEM fields, and their digital resilience at the outset and end of the course. A direct comparison between the data collected at these two entry points would draw out implications about the impact of the course on this cohort.

In line with the interview data, the baseline survey responses (total number = 23) suggested that students' confidence in using technology was noticeably high at the outset of the program. For instance, 92% believed they were "able to help others learn how to use technologies". 92% also felt "as capable as boys when fixing technical problems". Students' interest and motivation to learn about technology were also exceptionally high, where the data showed 100% "would like to know something about how it [technology] works". The ratings on the digital resilience aspects of the survey were also well above-average. For example, 77% agreed with the statement: "If I get stressed when technology doesn't work, I can overcome it".

When we compare this cohort's self-perceived technology confidence, interest, and digital resilience with the larger cohort of High school girls, which had taken part in previous studies, we come to the conclusion that the students participating in the art Masterclass had high intrinsic motivation for the course. What had contributed to and strengthened their motivation and confidence were their enjoyable prior experiences as well as their school's heavy focus on technology adoption. But, whether the art Masterclass equipped with the stem.T4L IVR kit could even further their passion and interest in STEAM was yet to be explored. In the following section, we will have a look at the students' year-long journey with IVR and the art project they produced by the end of the course, before moving on to the findings of this research.

# Students' journey with the IVR kit in the art Masterclass

## Learning about the IVR equipment

Week 5 of Term 1 marked the beginning of the art Masterclass. In the first three sessions, students learned about the overall aims and objectives of the course, shared their prior knowledge and experiences with VR, and were familiarised with careers that use IVR technology. Examples included professions like the defence forces, where IVR is used for training soldiers; or in aged care, where people with disability or mental health use IVR to experience digitally what they physically cannot.

A key focus of the initial lessons was on using the equipment effectively and safely, so students also learned, for instance, how the quick change in the screens, colours, or settings could trigger episodes for someone who has epilepsy. As shown in the picture below, taken during the first classroom observation, students also watched how-to videos, available on the stem.T4L Learning Library, which demonstrated how users should wear the headset, adjust the strap, and use controllers.

Behavioural and cognitive engagement was clearly visible through prolonged moments of silence and focus on the videos, as well as students' responses to teachers' comprehension questions such as:

Teacher: "*Why do you not enter the VR working area?*"

Students: "*Because the person [wearing headset] won't be able to see you.*"

Following the tutorial videos, students had their first attempt at the IVR kit set up in the photography studio. Taking turns, they put on the headset and explored the Tilt Brush program to start with.

Occasionally, the teacher took control to explain various functionalities of the software applications or the IVR equipment:

Teacher: "*This controller brings up the panel, and this one acts like a laser pointer so you can choose things*".

Technology caused occasional hiccups as students continued to explore the equipment. For instance, the cord that went from headset to the PC kept disconnecting. However, problem-solving skills aided the students. In this instance, one student held the cord and others taped it up to fix the connection issue. Students collectively managed to find solutions to such technical issues and everyone got the opportunity to try the equipment.

## Collaborating to generate ideas

Once students were familiarised with the equipment, it was time to come up with ideas and begin planning. Breaking into five groups of four to five participants, students were asked to collaborate with peers that had similar project ideas. Teachers' tips such as "*be realistic about what you want to do*" and "*find likeminded people and make a group*", helped students' navigate through this stage.

As shown in the picture below, the small group discussions were highly interactive. The students would walk to different groups and discuss their ideas with passion, humour and openness. The classroom atmosphere was busy and charged with enthusiasm, confidence and a willingness to share and learn.

To help students brainstorm, teachers shared IVR projects produced by other schools, and introduced likely possibilities such as creating interactive spaces or games, or designing tools to provide assistance or improve skills. However, given that the art Masterclass had a project-based learning approach and researching and exploring were key components of the course, first few sessions were largely about exploring ideas. Students also had the opportunity to look at digital artworks created by other artists for inspiration.

Once the ideas began to evolve, students were given a project proposal form with instructions to fill in the details of their proposed plan including: the equipment and materials needed, safety considerations they had to take into account, potential challenges that could arise at different stages, the kind of environment or setting they wanted to create, and the duration of the proposed project. Providing such level of detail created abundant opportunities for discussions, crystallised students' thoughts, understanding, and passion around technology, and gave them the confidence to express their creativity freely. Pictures below show two groups of students brainstorming and pitching ideas with passion and confidence.

During discussions of project proposals, collaboration dominated, with some students demonstrating leadership skills or taking initiatives (e.g., "*I'll make a new document for us*"). Snippets of dialogue also indicated entry-level vocabularies (e.g., "*virtual*", "*game*", "*experience*"), which soon led to higher-order thinking when considering design parameters and functionalities. For instance, in a group of five who were planning to create 'an underwater panic room with obstacles, set in Atlantis', attention to detail and critical thinking were abundantly clear. Also, brief moments of problem-solving occurred as they started to consider issues with the environment or content they wanted to create. Examples below were extracted from students' discussions on the panic room:

- *"There has to be a time limit on it"*
- *"How are you going to develop something underwater?"*
- *"Why would you be stuck there [panic room] in the first place?"*
- *"Will we need the headsets?"*
- *"What if you tame the shark?"*
- *"There should be clues or hidden messages – it'll be an educational question. The next clue will be, like, the habitat of a whale... It'll be educational but fun".*

## Working on a shared goal

Project proposals discussed by students were all fascinating, yet the teachers' plan was to choose only one proposal and get all students complete a project as one class. After much discussion and consideration, the final decision was to create a "Relaxation House". The idea was to create a house that offered a range of activities including meditation, cool down exercises, slow dance, singing, and digital drawings. By participating in these activities, the user could both enjoy a virtual experience and relax. But how were students supposed to design the activities? First, they needed to learn about programs available in IVR like Situ360 and Minecraft that could help them create immersive and interactive experiences. By watching the tutorials and exploring the functionalities of each tool, they began to comprehend the possibilities available to them and how they could harness the technology for creating an immersive art project.

Once they obtained some level of understanding of what lay ahead, it was time to outline a detailed project timeline and assign roles to each team member. In order to do so, the teachers, working as facilitators alongside students, provided scaffolding questions, requiring each group to complete tasks in two parts. In Part 1, each group defined their weekly goals, and wrote a follow-up reflection on the outcomes they had achieved in each session. In Part 2, they allocated jobs to each member based on their strengths and interests. The examples provided in the tables below, were taken from work samples of two groups:

Part 1: Complete a detailed project timeline to determine how long this project might take to complete. Think about everything that needs to be done. Be sure to add time for testing and editing the project.

| Term/Week | Lesson Goals | Lesson Reflection<br>What did you achieve in this lesson?) Were there any challenges? |
|---|---|---|
| Term 31, Week 1 | Group 1: Our goal this lesson is to create accounts for Situ360 and Tilt Brush. We will start watching tutorials and test out the programs.<br><br>We will also create a timeline and share our team member strengths/ jobs they will suit for this project. | Group 1: We learnt how to operate<br><br>Situ360 and Tilt Brush. We got more familiar with these programs. |
| Term 3, Week 3 | Group 2: Our goal this lesson is to start filming and to start gathering scenes and just general footage (audio, video and pictures). | N/A |

*Table 2: Lesson goals and reflection*

Part 2: Indicate jobs for each team member to manage project workload. How should we distribute the workload? Who will do what part of the project? What are the strengths of our team members? (Are they good at painting, drawing, filming, video editing etc.).

| Team member name | What strengths do they have? | What job will they suit?<br>(Photographs, Filming, Creating tuwtorials for activities, painting/drawing scenes etc). |
|---|---|---|
| Sarah | All | She can do all, however, there will always be a preference. |
| Kim | Filming, Photography | Filming, Photographs |
| Sofia | Drawing and Painting | Drawing and Painting |
| Kate | Drawing and Signing | |

*Table 3: Task allocation*

The five groups completed the above two assignments; each setting goals for their group and outlining what each member was expected to do. Some groups, as shown in the work sample below, demonstrated advanced project management skills and an understanding of the changing dynamics of teamwork that required them to be flexible, "*should there be any problems*":

## Work sample (Group 1)

"*Kim will film and take photographs. That part of the workload will be managed by her, and she will be expected to contribute to those topics and complete that work. If her work becomes unmanageable, she can negotiate with Sarah to help her with the work. Sofia will manage the drawing and painting work. However, she will work alongside Kate when it comes to drawing - all work between them will be shared and they are expected to complete and contribute to that work in an effective, smooth and accepting manner…*

*ALL the roles and responsibilities can be changed and will be changed, should there be any problems. Before changes, the teachers and/or mentors of this project will be notified and consulted with*".

After collecting each group's timeline and role allocation forms, the teachers reviewed each submission, proposed a timeline, and assigned tasks to each team member based on their qualities and interests. Once each student's roles and responsibilities had been understood and agreed upon, it was time to get the ball rolling.

## The art Masterclass in full swing. Data from second classroom observation

To get the project off the ground, the teachers provided each group with specific activities. Each week, the five groups collaborated tirelessly on their assigned tasks and moved one step closer to the final goal. The following section describes the first sets of tasks assigned to the five groups. The pictures included were taken during the second classroom observation in Term 3, and they vividly portray the initial steps on the way to creating a 360° model of the Relaxation House.

### Group 1 - Drawing Scenes for VR Project

Group 1 was in charge of sketching images of the rooms that would indicate the virtual spaces in the VR project. Students in this group started off with brainstorming ideas about the furniture and details of each virtual space, as per the instruction below:

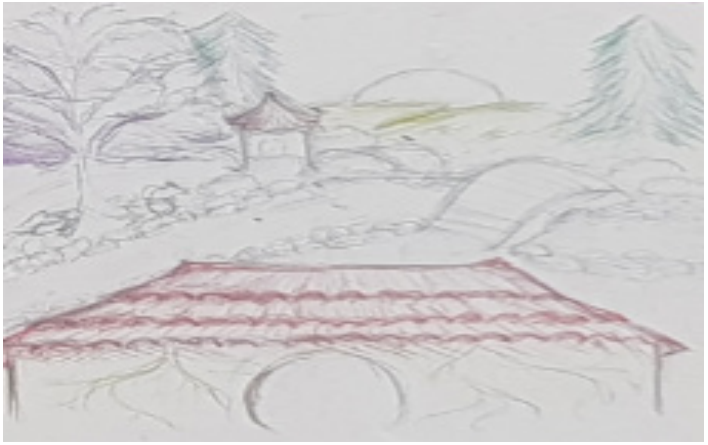
1. Brainstorm what decorations, furniture, details, features you would like to include in each room. The activities for VR project includes:

- Outdoor garden for Tai Chi
- Stage or music room for singing activity
- Garden, beach or mountains for meditation
- Library scene to read a book on Self-care tips

2. Draw each scene in as much detail as possible and colour it in (this will help us to draw it on VR Tilt Brush program).

Pictures below show the detailed sketches made by Group 1. As the activities were set in four specific settings (e.g. garden, stage/music room, etc.), Group 1 had to come up with ideas for four different sketches for the VR space. Students who participated in this activity were able to transform their enthusiasm, artistic imagination, and exciting ideas into striking images.

While working separately on their drawings, they exchanged ideas consistently and gave each other feedback.



*4 In Week 9, Term 1 the Masterclass took a pause due to COVID-19 restrictions. Towards the end of Term 2, the class restarted, however, the first two weeks were spent on reviewing and recapping knowledge from Term 1.*

## Group 2 – Storyboard

Using a storyboard template, Group 2 were instructed to create the screens that the user would see and interact with inside the virtual space, as explained below.

1. You have to map out the VR user experience. Write down the steps of how the user will navigate in the project we will create.

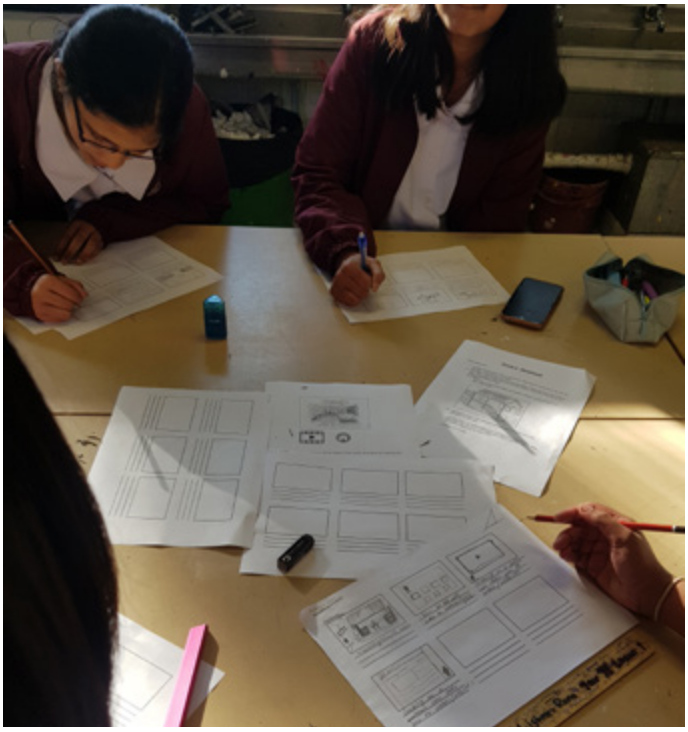
2. Think about what prompts and icons will be available to them and once a user clicks on them, what screen will they see? Draw exactly what the experience will be like on the storyboard template provided. For example:




- User sees the dashboard with options to select a range of activities in each of the rooms.
- User selects Room 1 (For example meditation room). (Icon/Button image references). User can click on the home button and it will take them to back to the dashboard. User can click on the video icon to play a mediation tutorial. Text can appear to guide user to click on links.

Icons can appear, text can appear in each scene. (Think about the hyperlinks and what page will they take us to).

To map out the user experience, Group 2 had to come up with a dashboard displaying the rooms and their activities. In order to do that, they needed to consider issues like: what the home screen would look like, what hyperlinks were needed to connect users to different spaces, how users could go back to the home screen, what users would see in each room, etc. Below is an excerpt of the storyboard template produced by Group 2.




## Group 3 - Explore Situ360 and create a sample project

Although students were briefly familiarised with Situ360, commonly referred to as Situ, during the first few lessons, it was time to sign up, create a sample project, and delve more deeply into its functionalities. To do so, Group 3 were asked to do the following:

**Task explanation:**

1. This lesson you have to log in to Situ360 or sign up using this link:

   *https://app.situ360.com/organisation/1379/signup?uuid=9f5836de-aa19-5154-ba54-5207480eab66*

2. Click on 'How To' videos and watch tutorials to help you understand the features and process of building a project on this program.

   *https://situ360.com/index.php/tutorials*

3. Create a sample project and include a few features from the program like adding a photo/video, adding a link, creating hyperlinks and adding text. You can use the sample videos and 360 images available in Situ360.

We can open this sample project in VR and experience it. We will use this program to build our project.

As the picture below shows, this activity was largely exploratory, with students trying to figure out initial logins for Situ or where content had been saved on their laptop; indicating an early foray into Situ. Students' interest in the activity was clearly evident, manifested in periods of silence and focused attention when watching Situ tutorials. Visible indications of their determined attempt to complete the activity included use of trial and error in the selection of images and scenes from Situ, and collaboration (e.g. '*How did you get to this tab?*' said one student to the other who was ahead of expectations in terms of understanding hyperlinks and other functions of Situ). When the teacher asked if they would be able to use links and other Situ content in future lessons, their response was very positive. Their learning achievement was noticed and recognised by their teacher when she assessed their class work on some of the more intermediate and sophisticated functions of Situ, as she commented: "*you've worked through this quicker than we thought*".

## Group 4 - Using 360° cameras

The task assigned to Group 4 was using 360° cameras to take photos from a space in school. Students were asked to refer to the how-to tutorials in order to confidently work with the 360° cameras, as instructed below:

**Task explanation:**

1. This lesson you will be using 360° cameras from the VR kit. The 'How To Use' tutorial is

   *https://www.youtube.com/watch?v=PF-fosDcY8w*

2. Your group will take one camera from the kit and a tripod to capture a space in school.

3. You will be able to use Situ360 and open your videos/images on this program to experience with VR headsets.

The experience of working with 360° cameras was filled with excitement and challenge, where complexities and wonder gave way to critical thinking, problem-solving, and collaboration. Two students, as in the picture below, appearing confident and animated when discussing functions of the 360° camera, encountered challenges including how to connect the 360° cameras with the iPhone or how to save pictures and videos. But it was not long before they figured it out and headed outside to test the equipment.

## Group 5 - Learning Tilt Brush

Another program that students needed to learn and use in their design was Tilt Brush. So, Group 5's role entailed watching the tutorials and having a hands-on experience by creating a sample project in Tilt Brush, as explained below:

**Task explanation:**

1. This lesson you will start by watching tutorials for Tilt Brush and learn the features of the program. Link for tutorials:

   *https://www.youtube.com/t?list=PLjhgRr1fomjOpHdrXVQrvKRWV1rVtEIPz*

2. You will log into the VR kit and in a seated mode you will have a chance to create a sample space using VR tools. You will be able to access Google Poly to import graphic objects into your space like a chair, toy, table, window etc. or ready made artworks/scenes.

   *https://poly.google.com/*

3. There is an option to capture a snapshot of your artwork on Tilt Brush, make sure you do this and capture a video of the artwork too. Students working with Situ360 will be able to use these images and videos to start to build our VR project.

Navigating the controller and finding the right functionalities posed a challenge, initially. The students in the two pictures below, were stuck and unable to apply the controller to perform specific functions. They discussed the issue with the teacher, but even the tips they received were not to their satisfaction. Seeing students unhappy with the outcome, the teacher suggested: "*we will find that part in the tutorial that explains about this bit*". Yet, these students were determined to find an answer on their own and hence kept on exploring. A few minutes into their trial and error process, they managed to find the right solution, which was well appreciated by the teacher: "*Yay, looks very nice, I am impressed. So glad you found out how to do it*".

Once students became more confident in using the controller, the teacher posed new questions, stirring up their intellectual curiosity and interest: "*I wonder how to close these small windows?*" "*How do we pin/unpin something?*" The questions motivated students to continually problem-solve and venture on trying new ideas.

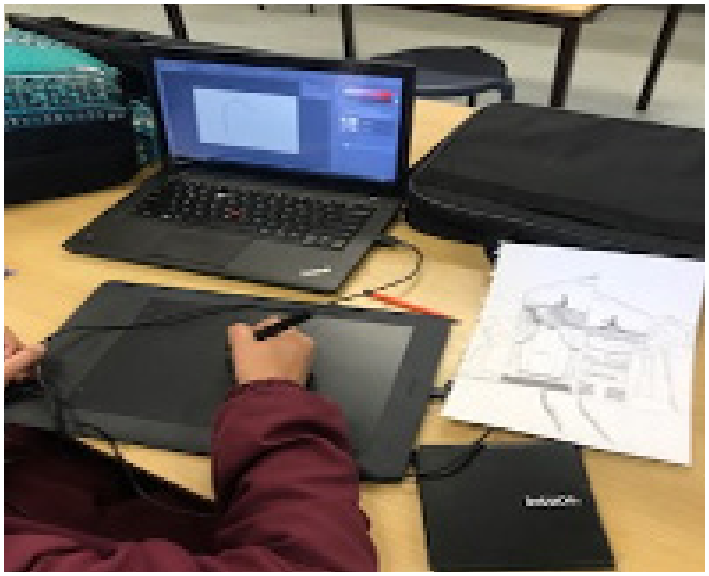
Classroom observations of students' first hands-on experiences with the IVR equipment provided the chance to see beyond their initial challenges or excitement to empirically evaluate their engagement with every step owf their learning process and draw conclusions from their actions and reactions. We found no student complaining or making half-hearted attempts at the activities. On the contrary, high level of engagement and enthusiasm for learning and discovering, facilitated through teamwork, problem solving and resilience, were noticed throughout the entire period. Behavioural patterns that emerged from the five groups were, to a great extent, similar, with students taking hesitant small steps into the unknown world of IVR equipment and software programs. But once their confidence rose and they developed some understanding of the "unknown", they did not hesitate to take control and explore possibilities on their own. Furthermore, high frequency of on-task behaviour, close attention to instructions, sustained interest and persistence in completing the tasks, and their personal and collective achievements were all indicative of their genuine interest and passion for advancing their understanding of art using the IVR kit.

Of note is the role of the teachers, who although tended to take a back seat and let students take ownership of their own projects, they did not hesitate to offer tips and feedback, or provide encouragement and compliment, especially when students had achieved some success. They would often explicitly articulate how "*impressed*" they were with the level of exploration and understanding that students had demonstrated. Dweck (2006) believes what teachers tell students about their abilities or what they can do influence their subsequent achievement or persistence. Our observation echoed this argument where we found that teachers' encouraging feedback further inspired creativity and instilled a sense of confidence, as the students expressed in their final interview.

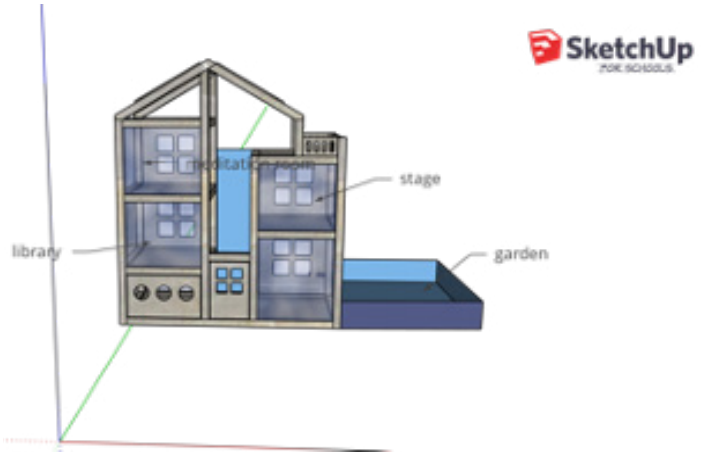
## Achievements and artwork

The two weeks following the second classroom observation were spent on similar activities as described above. Although students were instructed to continue to collaborate with their team members, they were also encouraged to reach out to other groups and learn about their progress and achievements. During this time, they continued to explore Google Tilt brush, took 360° photos to later upload them on to Situ360, learned more about the functionalities of Situ360, and completed sketching images of the scenes of the different VR spaces in the Relaxation House

Around Week 5, Term 3, in accordance with the NSW Department of Education COVID-19 instructions that restricted the gathering of different cohorts in one space at the same time, the Masterclass teachers regrouped students based on their year groups, and assigned new tasks. Teachers' notes on students' progress indicated that students worked seamlessly on the Relaxation House project and continued developing new skills. For instance, Years 7 and 8 used graphics tablet, as in the pictures below, to develop their skill in digital drawing as they sketched scenes for the VR environment. They also used Photoshop to edit 360° photos, and made necessary improvisations for final images.



The Year 9 group created a sample virtual reality project on Situ360 followed by testing the viewing experience in the VR environment. Year 10 students continued working in Google Sketch up to build a 3D section of the Relaxation House with different rooms to import and view in VR. The picture below shows the initial 3D dashboard of the House.



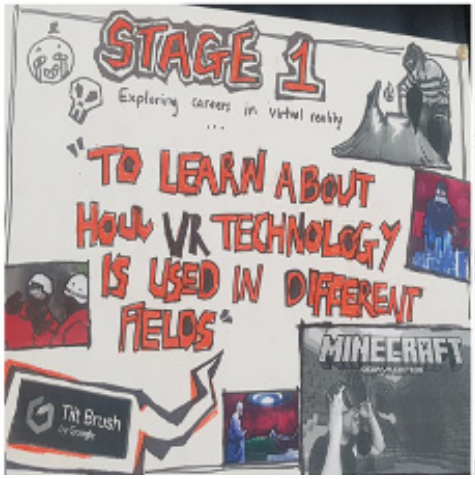

Once they completed the dashboard, they added tutorial links for activities in the Relaxation House including singing and Tai Chi to enable users to learn more about them. To enrich the VR experience, they used or manipulated copyright-free audio to play as background and theme music. The picture below, digitally edited and completed on Photoshop, is the draft version of the dashboard, portraying what the home screen looked like eventually.

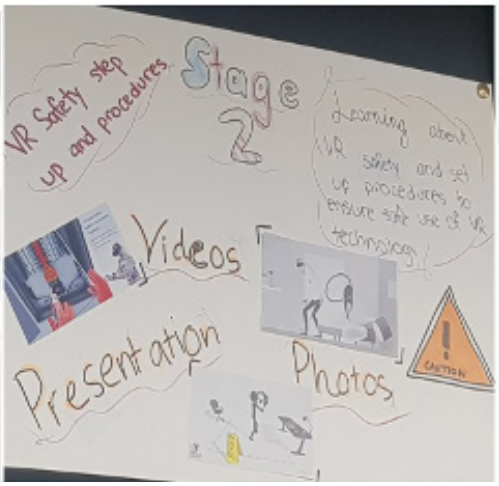
The two pictures below are the Meditation Space and the Singing Stage Scene both edited on Procreate by the students. These work samples were shared by the teachers.

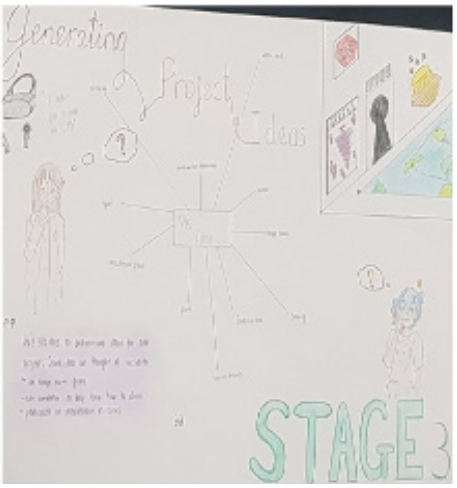
As Term 3 started to approach its end, there were only a few final tasks to complete including combining footage using appropriate programs and connecting tutorials in virtual spaces with hyperlinks to start an activity. With all those steps done, the last job was to test the VR project and make edits and adjustments.

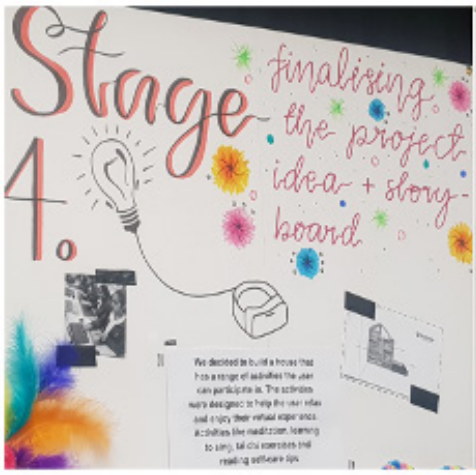
## The art Masterclass: End of the journey

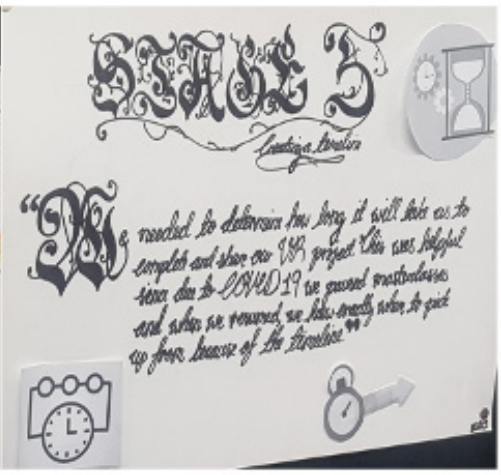
Early in Term 4, 2020, the art Masterclass came to a successful conclusion. To celebrate this remarkable achievement, the class offered a trial of their Relaxation House project, along with a poster presentation, where students showcased their amazing journey with the IVR kit. Using a combination of texts, drawings, and pictures, students depicted 12 stages that they completed to design their IVR art project, as shown below.

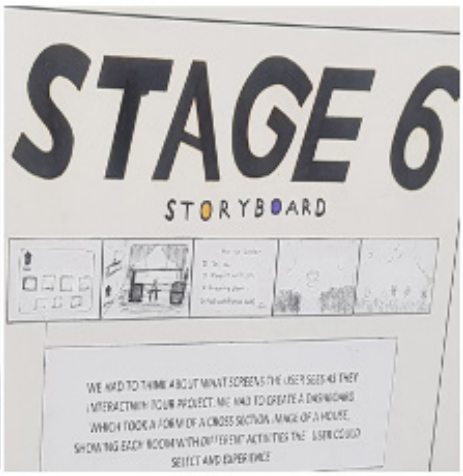

STAGE 1
Exploring careers in virtual reality
TO LEARN ABOUT HOW VR TECHNOLOGY IS USED IN DIFFERENT FIELDS
MINECRAFT
Tilt Brush

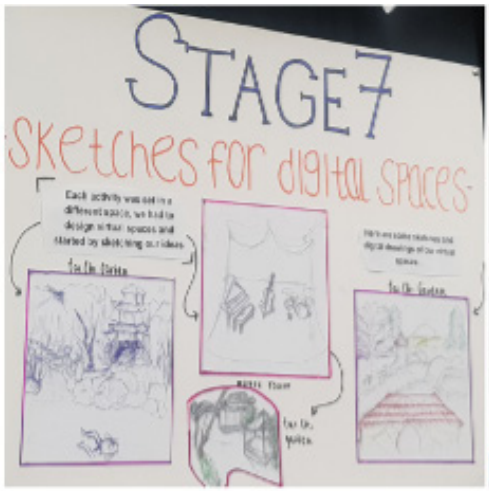

Stage 2
VR Safety step up and procedures
Videos
Presentation
Photos

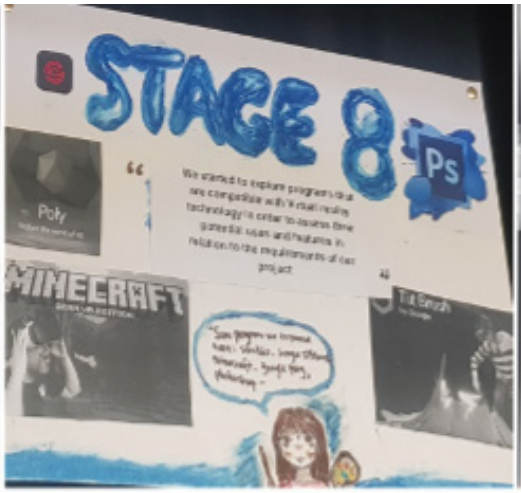

Generating Project Ideas
STAGE 3

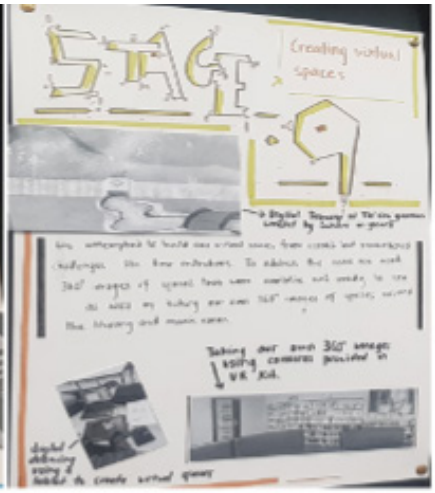

Stage 4.
finalising the project idea + story-board


STAGE 5

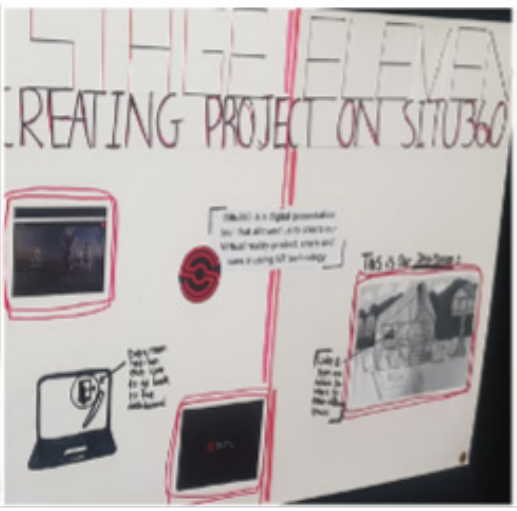

STAGE 6
STORYBOARD


STAGE 7
SKETCHES FOR DIGITAL SPACES


STAGE 8
MINECRAFT


STAGE
Creating virtual spaces


Stage 10.
Virtual Reality Headset


STAGE ELEVEN
CREATING PROJECT ON SITU360


Testing Stage 12 & Editing
AUDIO
VIDEO

The presentation was held during lunch time and students from all year groups, teachers and the principal attended the event and tried using the Relaxation House. To evaluate users' experience with their IVR art project, the students created a short questionnaire, provided below, which was distributed amongst all participants.

**User Experience Survey**

1. Are you a student or a teacher?
    a. Student
    b. Teacher

2. What age group are you in?
    a. Age 11-12
    b. Age 13-14
    c. Age 15-16
    d. Age 17+

3. What experience did you choose?
    a. Meditation Room
    b. Singing Room
    c. Tai Chi Garden
    d. Library (self-care)

4. What was it like? (Based on Question 2)

5. How could we improve our VR experience?

6. Would you recommend this experience to anyone else?
    a. Yes  b. No

16 participants filled out the user experience questionnaire where they all recommended the IVR experience to others. Based on the responses, it appeared that everyone who had tried the Relaxation House had really enjoyed the experience as the comments they wrote were all favourable, describing the House as "*relaxing*", "*cool*", "*calming*", and "*out of earth*". A few respondents had also given suggestions to improve the IVR artwork such as adding a game element to it or including more activities, features, options, or rooms. The picture below was taken from the Masterclass participants who attended the poster presentation day.

## Students' reflection on their journey with the IVR kit: Data from final focus group interview

As mentioned earlier in this report, a final focus group interview was conducted with a number of the Masterclass participants. The focus group was scheduled for the day students had their IVR project on display (Week 7, Term 4), so that the research team had the opportunity to try the Relaxation House project, and ask questions about the experience in the interview. To capture the diversity of views on the Masterclass experience, no screening requirements were imposed on participation, which meant even students who had not participated in the first interview (held in Term 1) could join. As such, a total of nine students, most of whom were not present in the first interview, came together to share their experiences, and reflect on their learning journey with the IVR kit.

All participants eagerly contributed to the discussion, conveying their immense satisfaction with the Masterclass and a sense of accomplishment that the stem.T4L kit had promoted. Their passionate engagement in the discussion lasted throughout the 45-minute interview. Evidently, this "engagement" was not unique to the discussion, rather it was the running feature of the Masterclass, as the interviewees pointed out. In other words, when asked about the general atmosphere sensed in the Masterclass, all participants agreed that engagement in learning and high excitement were always palpable in the room. This theme along with other topics discussed in the interview will be explored and discussed below.

### I could feel a kind of keen air of excitement

The day leading up to the Masterclass was filled with excitement. This was a sentiment voiced by all interview participants like Sofia who provided a vivid description of Tuesday mornings, when the Masterclass was on, to express a genuine enthusiasm she and her friend had felt for the course:

Sofia: "*In the morning, every time Jess and I came to school, Jess was like, 'Oh my gosh Masterclass', and I was like, 'Yay'. And then – especially at the end of the day, when all of us were really tired and we just wanted a new escape to a new world –we got to experience that with virtual reality.*"

Whether it was the "*laid-back*" and "*supportive environment*" of the art Masterclass, or "*a new escape to a new world*", or even the opportunity to learn about something they aspired to do in the future, it seemed "*everyone was just so happy*" and "*a little bit more excited*", or as Nora said, "*in their element*", when working with the IVR kit. This excitement for learning had manifested itself in a sustained engagement in the learning activities, which sometimes had even made these students stay back at school, engaging with their peers and collaborating on tasks, as Ann explained:

Ann: "*I remember most of the weeks, we would stay a bit past what we're supposed to. Because we got really engaged in the activity we were doing.*"

Such active engagement in the learning, according to the participants, was attributed to the way in which IVR tapped into multiple sensory sources (e.g. visual, auditory) to offer a multimodal learning experience. For instance, Elena compared learning through IVR with conventional teacher-centred learning, where a teacher would just "*talk*" to the learner. She argued that because they received "*lot more sensory information*" in the virtual reality environment, "*everything was definitely more engaging*". Isla voiced the same opinion and considered the course "*more engaging*" as it was "*a full day of verbal and visual learning*". Interestingly, several researchers who have explored learning facilitated through IVR have arrived at similar conclusions. They confirm that the multisensory and interactive nature of the IVR environment promotes user engagement and presence (e.g. Faiola, Newlon, Pfaff, & Smyslova, 2013), as observed by the focus group participants abundantly in their classroom.

In addition to a higher level of engagement, students had gained many lasting benefits and informal learnings from their IVR experience. The learning gains were so tangible and impressive that the participants were not able to converse about their Masterclass without alluding to or remembering a teachable moment. In fact, their takeaways from the IVR experience dominated the conversation and overshadowed any other discussion topics, as described in more detail below.

## Working as a group: Learning to be adaptable and flexible

Being a school-wide program, the art Masterclass had brought together students from different year groups, ages, backgrounds, and abilities, giving students a golden opportunity to closely interact, collaborate, and learn while working on a shared goal. It was, therefore, not surprising to learn that students had grown significantly more cognisant and respectful of differing views, opinions, and subjectivities arising from the group activities. Some of the interviewees like Aria and Kate explained they had come to realise "*we're a lot of people*" with "*very different talents*", but "*in the end we're just one big team*". So, the key was to tap into each person's ideas and talents "*to create one final project*":

Kate: "*The biggest takeaway was the fact that we're all really different people, and we're a lot of people, but in the end we're just one big team, we're going to do all of this together*".

Aria: "*People have very different talents. Some people are good at art, while others are good at things like maths. So, I learnt how to use all of those ideas to create one final project. Because if we can use everyone's talents and make everyone happy, while simultaneously making something awesome, then it's like an enjoyable experience for everyone and the product – the end result, the outcome – is also really good*".

Closely linked to the notion of mutual respect and recognition highlighted in the accounts above, was an understanding that teamwork required a considerable degree of flexibility. As mentioned earlier, the students were initially instructed to form five groups based on their shared interests and likes. However later in Term 3, they were regrouped according to their year levels to comply with the COVID-19 restriction guidelines. Moving between groups, however, was not a setback for the participants, as they told us in the interview, rather, an opportunity to exercise flexibility and adaptability to abrupt and unanticipated changes that might occur in a work environment like their project group. The interviewees told us about their experiences of how they had managed to positively react to a sudden shift in their role, and how that had made them more adaptable and understanding of the essence of teamwork, as described in the following examples:

Valentina: "*So we basically learnt how to move from different jobs smoothly and take over what other people had left behind really well. We also learnt to be more flexible in what we do*".

Nora: "*I moved around a lot between all of the different parts of the project. So, I wasn't really stationed at one technology, or job. So, for me, it was really rewarding to work with and guide other people*".

Hannah: "*I did move around a lot too, and I tried a lot of different things. Some I never even tried. Some I did. And working with different people in different grades, was really interesting as well*".

Ann: "*We were very flexible, very adaptable, just very accepting of everyone, their backgrounds, their stories, their limits, and their elements like the thing that they're good at. So, I think my biggest takeaway was how to accept all of that and just move on, like no matter what life throws at you, you can just keep on doing it*".

Isla: "*When you get new experiences – you end up creating new connections between all those neurons in your brain. So, in the end, I feel we learnt more things, but we also learnt how to be really adaptable and creative and more putting ourselves into other people's shoes*" (sic).

## Reappraisal of what art is and how it can be created

Using IVR as a tool to create art was undoubtedly a unique experience that created a profound impact on the way students viewed, appreciated, and presented art. Unlike their previous experiences, where they "*mainly just painted*", this year with the IVR they got to have "*a whole 360° experience*", that "*appealed to more than just one sense*". The IVR had opened up new horizons, leading to a realisation that art was not just "*on a piece of paper*", but "*a very broad sort of subject*", with "*so many ways of doing*". Such new conceptualisations of art resulted in implementation of new approaches by students, which clearly took their creativity to a whole new level, as demonstrated by Nora's waterfall example

below. The following excerpts from the students' focus group interview portray their newly developed understanding of what art entailed and the various possibilities that they had discovered for creating art.

Isla: "*I think because it's VR, so it's like sort of a whole 360° experience. So, there wasn't just like the physical sort of aspect of doing the art, it was also like sound and visual, and it appealed to more than just one sense*".

Aria: "*I think when people think about art, they think about a painting on a canvas, or maybe sometimes music. But I realised that art can – art is also like a very broad sort of subject. It can also be related to technology. It can also be something to do with coding. Art is like not just someone having a brush, painting something. And it's not just someone singing. It's like something really abstract*".

Elena: "*It showed a new way of art because instead of paper, being digital it expands the entire idea of art itself*".

Valentina: "*Last year what we did in Masterclass, we mainly just painted and everything. But then this year we made art digitally. And that was a really great experience because it was really easy, especially with – it was just like drawing in the air. And that was really fun*".

Nora: "*We had this scene where we had to take a waterfall picture, and what we did is that we put the 360° camera on the ground on the stand, and then we dropped the water from behind. And then after that we just added a little more water. We tried to create a waterfall in a space that was just some bush*".

Kate: "*I guess it's a different presentation of art. You just think of art as just on a piece of paper. It's 2D. You can't move around. But when it's 3D and all around you, you kind of realise how art has changed over time, how we change our perception and our presentation of art. And it's just kind of amazing how it influences art*".

Sofia: "*It's definitely expanded our horizons about what we can do, even with traditional art. The way you're painting, the style, how we engage with the senses*".

Hannah, agreeing with what others had said, brought a valuable extra dimension to the discussion. Clearly, working collaboratively on the Relaxation House project for almost four terms had familiarised her with the ins and outs of undertaking a creative project, making her realise the considerable effort that artists put in. Acknowledging the time and effort they spend on a piece of art, she called for greater appreciation for their work:

Hannah: "*I noticed how much time and effort actually went in to making one project, even if it's small. Like normally if we're assessing or looking at something that someone else made, on the internet or anything, we just look at it very subjectively as if it's interesting or not. And if it's not that interesting we just don't really give it much thought. But then I think we should because they probably put their time and effort into that, and they need a lot more appreciation*".

## There is much more to technology: A boost in confidence

The baseline data had previously indicated that the Masterclass participants were fairly familiar with the VR equipment. Obviously, their extensive hands-on experience gained recently through using the IVR kit had shed further light on its affordances and the endless possibilities that technology, in general, could open up. Although "*a bit overwhelmed*", as Isla said, they were all in awe of how much everything including "*learning*", "*communication*", "*mental and physical state*", along with art was enhanced by technology:

Isla: "*I'm a bit overwhelmed by how much there is and how much you might be able to learn*".

Valentina: "*I learnt that there's much more to technology... In the start of Year 6, we went to a university as well. But I wasn't that familiar with it, and I was like, "No, I don't think this is going to be fun, like all you do is just get in a headset and just play games", and I didn't think it was that interesting. But when I joined Masterclass I really learnt that you should try stuff out*".

Elena: "*I wasn't very exposed to the VR world. I mean I knew about it, but I didn't really know how it could help. And how technology could help us learn and*

*go into different careers. And VR can really help our mental state and physical state too".*

Kate: *"It's a bit scary to see how quickly technology evolves. Because in the future, VR could be such a common thing".*

Nora: *"It's the idea that technology is continuing to evolve and grow, and it's becoming a major thing in a lot of people's lives. And with that, it also expands our knowledge as we learn new ways of doing new things. So, not only art, but also learning and communicating with friends. It makes a new outlet for that".*

Ann: *"I realised that it's not just Google or all these other things that you know, everyone knows what to do, technology's bigger, and there's more things to it".*

The direct impact of a year-long exploration of the stem.T4L IVR tool was felt most keenly on students' confidence in their abilities to use technology. The interviewees all acknowledged that they had received an extra boost in their tech confidence. As Aria suggested, the higher confidence was the result of "*learning a new way*", and putting into practice skills they already had but they never had the chance to implement. With that confidence and self-assurance, Elena, for instance, was "*ready to answer*" any question related to VR:

Elena: *"I go to coding class in java script or something like that. But when they ask a VR question, I'm like, "OK, yeah, I'm ready to answer that. I know stuff about it. I've done it for four terms" and yeah, so I know the background information and I'm pretty good at it".*

Nora: *"I wasn't exactly confident with technology at the start. But I do think virtual reality has helped me be a little bit more confident with it".*

Aria: *"It's boosted my confidence. I've had experience with technology before, but learning a new way of implementing these skills, I feel like it's made me feel more confident in using technology, and enjoy it a lot more as well".*

Kate, confirming she had also experienced a surge in her confidence, considered "*practice*" and "*determination*" key to maintaining that sense of confidence, she said:

Kate: *"I think it definitely boosted my confidence. I wasn't that confident at the start. But like coming every single week, showing that determination, and then that dedication, and then practising and using those cameras, the programmes, and even at home maybe like using some of the new techniques with those programmes, that really helped as well".*

Interestingly, it appeared that the teachers were another source of confidence for the students; their knowledge and expertise, moral and technical support, problem-solving approach, and can-do attitude had adequately equipped students to confidently address the hurdles as they arose. Equally important was the 'guide on the side' approach they had adopted; meaning instead of a top-down, didactic 'teaching to the students' style, the teachers were there to provide guidance and scaffolding. In addition, their willingness to learn alongside students was a source of inspiration and motivation for the Masterclass students. The teachers broke down power dynamics in the classroom and promoted collaboration by letting their students know that they did not have answers to all questions but were willing to work together to find them, as suggested by Kate:

Isla: *"I feel like the teachers were also there to boost our confidence, 'coz we could go to them because they were really experienced with this whole thing. They just like clicked all these buttons and we were just like "Whoa". They knew everything, and I feel they're really amazing as well."*

Kate: *"For example, if you're visiting Microsoft Word after a long time, and you don't know how to create a textbox, you have to ask someone and they're like, "Oh my God you don't know how to create a textbox". So that makes me feel a little bit less smart. But then the teachers they didn't do that. They were like, "Oh it's fine. I don't know how to do that either, but I think this is how you do it".*

## The introduction of IVR has expanded the types of jobs I want to apply for

We cannot say with certainty that the focus group participants would reconsider their future careers to pursue a STEM related field after their experience

with IVR technology, especially because some of the participants were still undecided about their future path. However, what came out of the data loud and clear was that they all had more awareness of how different career pathways can benefit from IVR, and how technology, in general, and IVR, in particular, can transform and advance any field of study. The growing awareness of the significance of technology coupled with the confidence, generated by hands-on experience of using IVR, opened up new horizons for students. For instance, Hannah explained how the "*new experiences and ideas*" that IVR had given her, "*expanded*" her career options. Similarly, for Kate and Ann, increased confidence in their ability to navigate the digital world and knowing *"how to use it [technology] now"*, had sparked an interest in technology fields, where a career in this space had "*become a very possible future"*.

Hannah: *"My choices in jobs have changed a lot over the last few years. But it's always been something that either helps people, or incorporates technology as it becomes more dominant. And I feel like the introduction of IVR has also expanded the types of jobs I want to apply to, because it's given me new experiences and ideas"*.

Kate: *"I don't know what my career is going to be when I grow up. I have a small view of what I want to become, but I know that if that doesn't work out then there's always something technology related, or VR, that I can join, because I have some experience with it"*.

Ann: *"IVR has become a very possible future for me, especially with the experience, 'coz I know how to use it now (sic). I'm starting to think of the possibilities and how far I can take it into the world, and how I can share this experience with other people"*.

There were other students like Valentina who were fairly certain about their future career path; she wanted "to become a psychologist or a psychiatrist". For her, the insight gained though working with the IVR tool was particularly illuminating, as the idea of using IVR for people that have "stage fright" or "a phobia" had sparked in her mind.

Valentina: *"I want to become a psychologist or a psychiatrist in the future. But I realise that virtual reality could really help people. Like dealing with stage fright or when someone's really antisocial or maybe someone has a phobia of something, maybe it could be helped using virtual reality. Because it's like something's not really there, but because you're seeing it and you're hearing it, and in some cases, you're almost feeling it, it seems really realistic"*.

## It's a matter of opportunity: Technology is not gender specific

One of the issues that we explored in our first interview with students, early in March, was their perception towards negative stereotypes about women's abilities and representation in STEM. As explained in the earlier sections of this report, the participants in the first interview were collectively against any gender stereotypes prevailing in public discourse, rather, they considered resilience, interest, and passion as the driving forces. In the final interview, we revisited this topic and received a similar reaction and response. Nora, for instance, drawing upon her recent observation of both male and female teachers trying out their project, pointed out that technology would appeal to "*everyone and anyone*", "*regardless of their gender*". Hannah, agreed and added that having the "*opportunity*" to learn is what makes all the difference; once given the opportunity, everyone "*will learn*":

Nora: *"I feel like it's similar, because even our male teachers came and actually tried out the VR headset, and they had the same enjoyable experience as the female teachers. So, I feel like technology is something that everyone and anyone can use, regardless of their gender, age or anything"*.

Hannah: *"It's a matter of opportunity, because if you give someone a headset, they'll learn". It's not anything so fancy that can be gender specific. You just need the opportunity to try it out, play around with it and think about whether you like it, what you can do with it"*.

Although gender was not a predictor of interest or innate abilities in technology, as some students argued, it could shape the learning dynamics in a classroom setting, according to a few others. For instance, for someone like Kate, learning was more effective in a "*comfortable*" girls-only environment. Kate went on to establish a link between effective learning and comfortable "surroundings", where the former, she argued, was contingent upon the latter.

For Ann, on the other hand, collaborating with an opposite gender and learning through sharing "ideas and thoughts", could be as advantageous as learning in a girls-only school:

Ann: *"I feel like it would also be a good experience to work on a project with a different gender. Like you get to know other people, and also how they think. Because sometimes girls can learn faster than boys, and some boys learn faster that girls. So, then we can share ideas and thoughts with each other".*

Kate: *"I think 'coz all of us were girls, we were more comfortable as well using it (sic). So, that's a positive, because if you're not comfortable in your surroundings, you wouldn't really learn effectively and that actually made it really a good thing for me especially".*

As the examples above suggest, there was no indication that working with IVR had significantly altered girls' perceptions of what they could or could not do compared to boys. Rather, their new-found understanding of the affordances of technology and their enhanced competence to use IVR had fostered deeper motivation and appreciation for learning, especially for creating digital art.

## Challenges and insights

The last portion of the discussion centred on the challenges that students had confronted over the course of the project. We anticipated that the students would specifically focus on difficulties or hurdles they faced in using the equipment. To our surprise, the only challenges they discussed centred around interruptions caused by COVID-19 restrictions; in that, they had to relearn a few things after they had resumed their Masterclass, or they needed to work around the restrictions introduced on group work, as Kate and Sofia explained:

Kate: *"COVID was a big deal. I mean we had to halt everything in about Term 2 because of this whole COVID thing, and we forgot a few things, or we had to relearn them when we came back. And it was just kind of a tough thing to work around... It was just a hard experience, but we learned from it".*

Sofia: *"Yeah, because of the COVID restrictions also different year groups had to be separated, so that was one of the difficulties we had. But still we did share and we did worked together really well"* (sic).

Apart from issues caused by the pandemic, Aria pointed out that Wi-Fi connectivity was a setback at times:

Aria: *"We had trouble with the Wi-Fi sometimes, and it really took most of our time, – we were actually going to test it [IVR kit] but then it said, "Internet is not available". So, then we tried to add in the internet cables and everything, but then that didn't work. So, I think at least three of our lessons we had to spend on that".*

Listening eagerly to the conversation, Ms Gifford chipped in with a comment that shed further light on the conversation. She pointed out that although stem.T4L's how-to videos and instructions were all "*explicit*" and helpful, the students' "*proactive*" approach to access the videos and find answers when they were uncertain and overwhelmed was noteworthy:

Ms Gifford: *"So stem.T4L made it quite easy for us to use this equipment, because it was overwhelming, and you're like "How do I connect all this, and how do I use it". But their videos had really explicit instructions and that helped us pick up everything really quickly. But I have to say though, the girls were really proactive in just going in and accessing these videos, and learning it in their own time, to make sure they understand how to use the equipment".*

So, based on Ms Gifford's comment, it became clear that COVID-19 and occasional Wi-Fi issues were not the only obstacles for the students. However, the problem-solving approach they had adopted, manifested in their use of videos and instructions as a go-to source, was instrumental in removing complications and getting things back on track.

At the conclusion of the interview, we gave the participants the chance to voice any concerns or comment on their overall experience with the IVR technology. Some students like Elena and Isla, used the platform to communicate their personal assessment of stem.T4L to other students. Viewing it as a "*very valuable*", "*unique*", and "*positive*" experience, they both encouraged everyone to give it a go "*when the opportunity comes*":

Elena: *"I think it should definitely be an opportunity that a lot more public schools can experience because, as you've probably seen with our project, we really had a lot of fun with it and it's provided a very valuable experience to all of us. So, I think that other students should also be provided this experience, so they can explore it and maybe even come up with their own opinions and think about their futures with technology and things. Because it's definitely a very positive and big learning experience".*

Isla: *"Yeah, I agree with her. I feel like this experience is really unique. Like I will go back to my family and say, "I experienced VR and you didn't". And then they all want to experience it as well. So, when the opportunity comes, everyone should take it".*

The qualitative data, as detailed above, suggested a noticeable increase in this cohort's attitude and understanding of technology, in general, and their interest and confidence in using technology for creating art. In order to measure the extent of improvement in the variables under study, and holistically evaluate the impact of the art Masterclass with IVR, we collected quantitative data as well. We mentioned earlier in this report that the Masterclass participants (n=23) filled out a pre-survey in March, at the outset of their course. When we ran the post-test in December, only 15 students attempted the survey, 13 of which had completed the first survey. From the additional data the teachers provided, we found out that some of the students who had participated in the first survey, did not stick with the course and went on to do something different. Although later in Term 1 more girls had joined the Masterclass, we did not collect any baseline data on this new cohort. Therefore, the total number of responses considered for the purpose of data analysis was 13. Below, we compare the findings of the pre and post surveys to draw overall conclusions.

## Post-survey results

The post-survey consisted of 34 multiple-choice and open-ended items, identical to the pre-survey, and measured variables such as students' digital resilience, 21st century capabilities, confidence in using technology, and "concept of technology" (Baskette & Fantz, 2013). The multiple-choice questions measured students' level of agreement (Strongly Disagree to Strongly Agree) with the items of the survey, using a 4-point Likert scale. To ensure higher reliability of the data, the items were adopted from existing instruments with established content validity (e.g., Baskette & Fantz, 2013; Moyer, Young, Weckman, & Cutright, 2015).

One of the key sections of the pre and post surveys was directed at measuring students' "concept of technology" (Baskette & Fantz, 2013), where students were asked in an open-ended item to explain what first comes to mind, when they hear the word *technology*. Of interest and significance was the difference made in students' conceptualisation of technology and whether their thinking of what technology encompassed would change from before to after the course. The data collected at the two time points was compared semantically and statistically, and interesting results were found; for 69% (n=9) of the pre-survey respondents technology meant "*devices*" or "*anything digital*". This figure dropped to 46% in the post-survey. Put differently, five students adopted a more "holistic view" of technology and applied advanced thinking to their interpretation of technology by the end of the course. For instance, as shown in Table 4 below, for Celina, technology initially meant "*anything to do with laptops and computers*". As her post-response indicates, after working with IVR for almost a year, technology became "*a very broad topic*" to her; one she could not confine to one form or a single category. Similarly, Elena moved away from viewing technology simply as "*devices*", to appreciating its far-reaching impact on "*modern society*". For Farrah, technology which was once about tools like "*computers, laptop and phone*", now was interwoven into every aspect of life, shaping the "*future generation*".

Maryam and Amara, unlike others, displayed a deeper understanding of technology at the outset; they could see technology as a key to "*analyse our world*", or to make the world "*easier or more connected*". The post-survey results showed that both respondents maintained a similar view and continued to attach high significance to technology. For the other six respondents, no difference was observed in their pre and post responses, with "*devices*", "*phones*", and "*gadgets*" being their first line of thinking.

When you hear the word technology, what first comes to mind?

| | | Pre-survey (March, 2020) | Post-survey (December, 2020) |
|---|---|---|---|
| **Shaila** | Year 9 | Anything that can be used to help people with everyday tasks or activities. | When I think of technology I think of a device that has the possibility to make change and make society a better place. It is the idea of innovation and invention. |
| **Celina** | Year 7 | Devices and anything to do with laptops and computers | It is a very broad topic and I think this topic is very interesting. I would think of this as becoming one of my career options. |
| **Elena** | Year 8 | Devices | The advancement of modern society. |
| **Farrah** | Year 10 | when I hear the word "technology" It reminds me of Computers, laptop, phone, information systems and social media | Future generations |
| **Laila** | Year 7 | Anything digital | I think of science and the application of science in human life. |
| **Amara** | Year 8 | Modern inventions allowing us to understand and analyse our world and use them as sources of education and entertainment. | Items which may assist people in completing a designated activity for which the technology is designed for. The type of technology which first comes to my mind is digital tech. |
| **Maryam** | Year 8 | Something which makes the world easier and faster and more connected. | Devices, using scientific and maths knowledge, developing online skills and learning more about apps and games. |

*Table 4: Students' pre and post-survey perceptions of technology*

Moving on to other variables of the surveys, we discerned inconsistent patterns of thinking in students' pre and post responses. While improvement was observed in the ratings of a few items, suggesting intellectual growth and positive impacts of the course, some items remained unchanged or the ratings dropped slightly. When asked to determine their level of agreement with the statement "Technology is rigid and inflexible to interact with", one of the items of the "Attitude towards Technology" variable, 69% disagreed in the pre-survey, displaying the positive attitude that with "trial and error" one can always find a way. In the post-survey, this number increased by 16%, suggesting that even a higher number of students (85%) found technology to be "flexible". However, despite improvement on this item, other items of this variable such as "when students use technology for learning they collaborate more", remained stable from pre to post testing.

Out of seven items measuring students' digital resilience, four showed growth from pre to post-survey. For instance, initially, almost half of the students (54%) agreed that they would "continue to work with new technology even if [they] did not know how to complete the learning activity successfully". In the post evaluation, 77% students agreed with the statement, suggesting that digital resilience, as a capacity to persevere when faced with technological challenges, had improved by 23% by the end of the course. For the statements "If I get stressed when technology doesn't work, I can overcome it", and "When technology doesn't work the way I want it to, I can look for solutions myself", we observed a boost in students' agreement level by 8% and 23%, respectively. Yet, the other three items of this variable did not show any improvement in the ratings by the end of the course. Similarly, the variable measuring 21st century skills, consisting of seven items,

produced mixed results: students' self-perceived "problem-solving skills" improved from 69% to 92% (23% increase), as did their ability in "finding new ways of doing things" and "understanding how things work" (8% increase). Yet, students' self-perception of their "leadership" and "communication" skills declined by 8%, on both accounts. Confidence in using technology was another variable included in the surveys, which did not experience a rise in the post-assessment, meaning the survey respondents did not have a higher evaluation of their confidence level at the end of the year.

As the ratings indicated, no consistent improvement was found across the items of the variables under study from before to after the course. The data also did not suggest a decline in students' evaluation of their abilities, confidence, and attitudes towards technology. Inferential statistics such as T-test could accurately determine the statistical significance of the differences between the means of pre and post variables, to indicate the effect size of the Masterclass. Unfortunately, because our sample size of 13 was much smaller than the "magic number" required for statistical analysis (n≥30), running a T-test was impossible. Therefore, the quantitative data was inconclusive in determining whether the art Masterclass with the IVR technology had any influence on the students. However, the qualitative data (i.e. students' interviews) suggested otherwise, as explained in the preceding section. Another source of data, which confirmed that the course had a significant positive impact on students, came from a final interview with the two teachers of the Masterclass. The highlights of this interview are presented below, followed by a final discussion.

## Masterclass teachers' final interview

Ms Gifford had come across VR technology last year in an exhibition at UNSW, where she had found herself fascinated and wondering "*Oh my goodness, imagine being able to use this at school with our students*". She felt "*very fortunate*" this year when she heard the school had borrowed the IVR equipment through the stem.T4L project. Yet, Ms Gifford and Ms Kataria were both hesitant when they first received the kit and "*had no idea how to use the equipment*", as they had "*never used an IVR kit before*". They could see the possibilities, and they were "*as excited as the kids*", but not knowing how to use the actual equipment was "*scary*"; even "*the thought of it was difficult*".

But the teachers were determined to give students the opportunity to see "*what it's like to create a project and everything that goes into a project*". Using a project-based approach- something that the teachers were well familiar with and had always adopted, provided a positive reassurance that this was not going to be "*too different*", the only difference was the technology, as Ms Gifford clarified:

*"Because each project we do in art, we start to brainstorm, we discuss, we talk, we do, we find solutions to a problem, and produce a final product. So, when you think about this as being a very similar task, similar activity, and all that makes it different is the technology".*

Yet, as the IVR was a new tool to the teachers, they needed to learn how to use it: "*like everything else, you have to actually do it a few times before you get used to it*", Ms Kataria said. So, the teachers made time "*to learn*", watched the "*available videos*", "*developed ideas*", and found ways in which the IVR could "*simulate a real-life experience*". This is how the Masterclass teachers set out on their journey with the IVR, which they thought could help other teachers get started with any new technology. Although they stumbled through the way, they "*got there eventually*". The outcome they achieved (the Relaxation House), which students had created based on "*almost nothing*", in their faculty "*with their art teachers*", and not necessarily with their "*science teachers*" was a badge of pride that the students should wear, Ms Kataria and Ms Gifford emphasised.

The informal interview with the two teachers took a few turns before settling into a candid discussion about students' unique characteristics that made the learning journey so fruitful. Initially, the teachers told us how proud they were of the students' active participation during their focus group interview, and the intellectual maturity they had shown was a true reflection of "*what teaching is all about"*:

Ms Gifford: *"I was watching as they were doing the interview with you last week. And I listened to how well they were speaking. They were so articulate. I just felt, 'this is what teaching is all about'".*

Ms Kataria: *"I just loved actually listening to them answering the questions that you asked. And it wasn't like they stumbled for thought. They really thought, 'Oh this is a possibility'"*.

But, one of the most praiseworthy abilities that the students had demonstrated throughout their journey, according to Ms Gifford and Ms Kataria was "*resilience*". Both teachers were in awe of their students as they did not let anything stop them and they remained "*very positive the whole time*". When there was a change of plan, either due to technical issues or unexpected hurdles, and the teachers had to shuffle students around, assign new activities, and readjust expectations and goals, and they would ask: "*this is what you have to do, can you do this, can you work on that?*", the students would wholeheartedly embrace the new changes and learn to become agile. Recounting some classroom experiences, Ms Gifford shared how students just said "*Yep, OK*". "*Let's redo the drawings. Let's re-outline certain things so it can make it look more 3D*".

Another major feather in teachers' cap was the sense of autonomy and a self-directed learning approach their students had consistently utilised when working with IVR as new technology. Undoubtedly, the teachers' strong focus on student-centred learning had acted as a catalyst for the increasing level of learner autonomy students had exercised. In the interview with the students, we heard them frequently say that they (i.e. students and their teachers) were "*learning together*". During the teachers' interview, the same idea was brought up where both teachers pointed out that they never took a know-it-all attitude, but provided "*very minimal instruction*", and put their students in charge of their own learning. Reflecting on her role, Ms Kataria said: "*The role of the teacher is that you should always, yes, you be the teacher, but sometimes you are the learner, and the role reverses. And that's how it should be in a way*". The outcome of such an approach resulted in students finding a sense of ownership of their learning process, and taking "*a lot of initiative to actually learn it themselves*", as Ms Gifford elaborated:

*"So, in terms of us teaching how to use the programmes, it was very minimal instruction actually. They picked it up so quickly... And they said, "OK. No, no, we can do this". They took a lot of initiative to actually learn it themselves".*

The Masterclass students had also displayed active engagement and interest in the learning activities throughout the course, the teachers pointed out. Ms Gifford believed that what initially "*drew the crowd*", was that the course was a virtual reality experience as opposed to "*looking at art as in traditionally drawing and painting*". She remembered how more than 30 students had signed up for the course, and there were more who wanted to join, and how they "*had to turn some away*". This encouraging response from students was an indication of their genuine interest in learning with IVR. But what maintained students' interest throughout the year was seeing and feeling "*the potential that art can actually be more than just painting, drawing, and sculpture. It is actually in many different forms*", Ms Gifford reasoned. More importantly, Ms Gifford argued IVR with its potential to tap into different learning subjects, "*not just Science, or English, or Maths*", had provided "*cross-curricular learning opportunities*" for students. The fact that the teachers "*never had to chase [students] up*" and "*there was really no complaints from the girls*" were telling examples of students' high engagement and growing interest in creating art with IVR - something that did not end with the Masterclass but "*went beyond the project*".

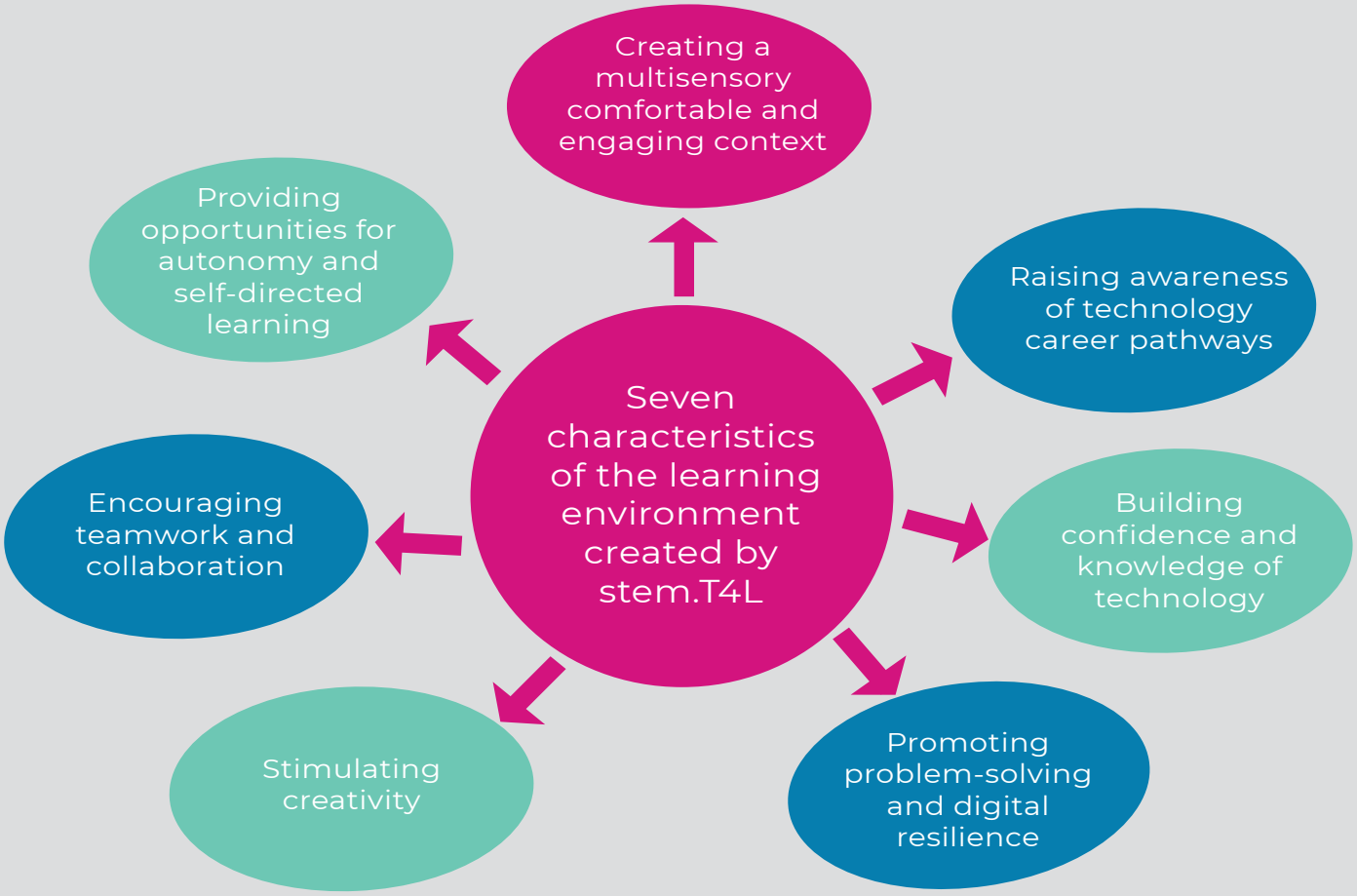
## DISCUSSION

The STEM pipeline for women is "leaky at every point" (Australian Academy of Science, 2019, p.5), which is why it is crucial for the education system to provide teaching and learning environments highly conducive to girls' learning and engagement in STEM. Creating stimulating environments is an ideal first step, but it is not complete without an understanding of what works and what does not in practice. We see such strong focus on evaluation in the "women in STEM decadal plan" developed by the Australian Academy of Science (2019), where they propose six strategies for Australia to improve gender equity in STEM. Among the recommended approaches is evaluating the extent of the effectiveness of STEM initiatives and programs, without which, they argue, it is difficult to know which programs to extent or scale up. What we add to that discussion, is a female-focused approach to reflect female voices when evaluating the impact of STEM initiatives, which, as alarmed by other researchers, is often absent in a male-female discourse (Osborne & Collins, 2001).

Blacktown Girls after-school art Masterclass was an incredible opportunity to examine the impact of stem.T4L on girls, specifically. We knew from previous research on this project that the learning environment equipped with stem.T4L technology abounds with opportunities to explore, engage, reflect, problem-solve, and learn. This time, we were interested to know whether the stem.T4L IVR kit, when incorporated effectively and adequately in a girls-only school, had the capacity to positively impact the learning environment, create higher engagement amongst girls, reform their understanding of technology and its affordances, and hence spark their interest in STEM-related fields.

Studies have shown that learning environments that promote creativity, collaboration, and hands-on learning experiences; foster a community of practice; constructively challenge ideas; and spark curiosity, dramatically influence girls' interest and persistence in STEM subjects (Cooper & Heaverlo, 2013; Gomoll, Hmelo-Silver, Šabanović, & Francisco, 2016; Renninger, Costello Kensey, & Lehman, 2015). So, was the stem.T4L learning environment hospitable to the Masterclass students to begin with and, if yes, what were the key characterises of that environment? To answer these questions, we reviewed and examined the extensive interview transcripts as well as the researchers' notes and reflections on classroom observations and looked for clues as to how the classroom dynamics, behaviours and attitudes, actions, reactions and interactions and, the overall atmosphere were shaped by the implementation of IVR technology.

We identified seven characteristics of this learning environment, shown as a graphic representation below, and we conjecture that these defining features favourably influenced the learning and engagement of students and contributed to the achievements gained.



## 1. Creating a multisensory, comfortable and engaging learning context

After-school programs offer "a looser accountability" structure (Gomoll, et al., 2016), which means students can quickly disengage from the activities if they are not highly interested and motivated in the learning. Interestingly, research on learning devices like IVR suggests that the human-computer interaction created by IVR generates stronger motivation for learning through offering a multisensory experience, leading to an increase in students' sense of presence or engagement (e.g. Huang et al., 2020). This argument corroborates the findings of our research. In fact, higher engagement and strong motivation for learning were noticeable in the Masterclass during the two classroom observations, where we documented students' behaviour patterns. Sinha, Rogat, Adams-Wiggins, and Hmelo-Silver (2015), identify four types of engagement: behavioural, social, cognitive, and conceptual-to-consequential.

The high frequency of on-task behaviour (behavioural engagement), contributions to group work (social engagement), planning and role allocation (cognitive engagement), and applying their knowledge of technology in new situations (conceptual-to-consequentialengagement) were credible evidence to suggest all students were consistently engaged in the activities.

The focus-group interviews with students and teachers similarly indicated that student engagement was a conspicuous feature of the Masterclass that strengthened their motivation to stick around and persevere until they completed the project. As engagement is a strong indicator of interest (Gomoll et al., 2016), we strongly believe that exposure to IVR contributed to higher interest and motivation for creating digital art through increasing student engagement in learning.

## 2. Raising awareness of technology career pathways

Lack of awareness of STEM career options appears to be one of the main contributors to gender disparity in STEM (Australian Academy of Science, 2019). A powerful way for girls to learn about the significance of STEM fields is to explore STEM applications in real life (Kesar, 2017). We observed that through the real-world application of IVR technology, students: (1) learned to appreciate the various possibilities that technology offered for creating art, (2) became familiar with fields that use IVR technology, and (3) built a deeper awareness of career opportunities that could come their way when they are equipped with 21st century knowledge, skills and attitudes.

## 3. Building confidence and knowledge of technology

As Bandura (1997) posits, "Mastery experiences" are powerful sources of self-efficacy beliefs, meaning mastering a task, overcoming obstacles, or controlling an environment conveys a powerful message of succeed, an immediate effect of which is an increase in one's confidence. Students' success in creating the Relaxation House, a digital piece of artwork, bred a notable sense of confidence.

As all interview participants pointed out, they had felt a boost in their confidence, rooted in their self-belief that they did succeed in using IVR to create digital art.

We also observed a pronounced shift in several students' understanding of technology, where their recent experience with IVR added further dimensions to their conceptualisation of technology, moving them from the realms of "*devices and phone*" to a place where technology meant "*application of science in human life*".

## 4. Promoting problem-solving and digital resilience

Increasing attention has been paid to cultivating enterprise skills such as problem-solving or critical thinking, as they are essential capabilities in students' STEM development (Baine, 2009). IVR technology appears to be an effective tool to enhance students' problem-solving skills as its 3D environment allows users to integrate information from different perspectives, view abstract objects in a concrete and visual manner, and mentally rotate items, all of which are key elements in problem-solving skill development (Passig, Tzuriel, & Eshel-Kedmi, 2016). Gradual progression of students' problem-solving skills was visible in the Masterclass, which was likely to be the by-product of the application of IVR. Another influential factor was the project-based learning instruction adopted by the teachers. Such approach to learning created ample problem-solving situations for the students including learning how to: (1) define a problem (i.e. how to create a tangible product within the IVR environment); (2) generate ideas as to how to approach the problem situation; (3) adopt technical and creative solutions to articulate the problem; (4) utilise a range of software applications and tools to modify and enhance the selected solutions; and (5)

solve a real-world problem in diverse ways, which resulted in producing a digital artwork that could provide an immersive and multisensory experience for the user.

The how-to videos and tutorials students consistently referred back to also allowed students to transfer the learned knowledge to the physical world step by step, which in turn impacted their problem-solving approach and resilience.

The interview with the teachers confirmed this argument as they shared with us how students never gave up solving the problem, and "*did not let things stop them*", suggesting how "*incredibly resilient*" they had become.

### 5. Stimulating creativity

The importance of creativity and innovation, along with problem-solving, as essential skills required for 21st century, cannot be over-emphasised. Yet, we continue to witness how a focus on rote learning, an endeavour to teach to the test, and a crowded curriculum that leaves no room for students to be imaginative (Shulman, 2020), "successfully kill creativity" (Robinson, 2007). Nonetheless, exploration, experimentation, collaborative learning, using imagination, taking risks, being open to ideas, and autonomy are some effective ways to encourage creativity (Cherry, 2020; Clifford, 2012).

We were pleased to observe that the stem.T4L environment lent itself perfectly to many situations that required students to step outside of the box, embrace new ideas, become decision makers, and take charge of their own learning to become creative thinkers.

### 6. Encouraging teamwork and collaboration

From the very early stages of the Masterclass, students learned that working towards a shared goal like creating the Relaxation House, would necessitate extensive amount of collaborative work, consistent engagement in open and constructive discussions, and genuine respect for everyone's ideas and viewpoints, which would all eventually enhance the learning experience and the quality of the project they would produce. As the pictures taken during classroom observations suggest, hands-on and experiential learning with IVR paved the way for such collaboration and teamwork, bringing together students from different year groups with different skills and strengths to share ideas and learn from each other. There were individual activities such as drawing the sketches or self-exploratory experiences that might place a momentary pause in the degree of collaboration between students. Yet, even in those moments, students engaged in a back and forth process of giving and receiving feedback, with a mindset of innovation and growth, which also helped them develop synergy and friendship amongst themselves.

### 7. Providing opportunities for autonomy and self-directed learning

Self-directed learning as a process wherein students take initiatives to become autonomous learners and in charge of their own learning, is proven to be positively correlated with use of technology (e.g., Rashid & Asghar, 2016). In the stem.T4L classroom, great opportunities existed to exercise autonomy. The various characteristics of self-directed learners are identified in existing literature (see for example Doering & Henrickson, 2015; Mok, Leung, & Shan, 2005). Many of these attributes were demonstrated by the students of the art Masterclass. For instance,

once being directed towards the right platforms to check the affordances of a particular learning tool, students driven by their self-motivation and sense of curiosity would begin to explore avenues on their own, applying their new skills and knowledge into problem situations.

When asked to complete the project proposal form, they collaboratively defined goals for their own group, allocated roles to each member, and set a timeframe to achieve what they had planned for, which were all indicative of their capability to regulate their thinking and learning strategies and actively participate in the learning. As explained earlier, the Masterclass teachers played a substantial role in promoting students' sense of autonomy where they worked as a safety net; providing guidance and constructive feedback throughout the way, and empowering students to become decision makers and take charge of their learning.

## Establishing a link between IVR and Syllabus outcomes

A key question that we need to explore in this section is whether the learning that took place in the Masterclass, as discussed by the research participants, and mirrored in the characteristics of the stem.T4L learning environment, was linked to any Key Learning Areas (KLAs). In other words, does the

integration of the stem.T4L IVR kit enable students to meet any syllabus outcomes? The answer is yes.

Although in this study, IVR was implemented in an after-school setting with an aim to mainly provide a novel art-making experience for the students, IVR can have a wide range of curriculum applications across different stages to contribute to students' learning and help them achieve syllabus outcomes. As Table 5 suggests, Visual Arts, Photographic and Digital Media, Visual Design, Technology Mandatory, Digital Technologies and Working Scientifically are a number of Focus Areas that create a meaningful context for IVR. Take Visual Arts as an instance. The varied software applications (e.g. Tilt Brush) and equipment (e.g. 360° cameras) embedded in IVR environment lend themselves well enough to an investigation into visual arts, where students autonomously venture into exploring and manipulating different techniques and materials to create arts beyond canvas and paints (e.g. outcomes 5.1, 5.4, LS.2). Based on our research findings, we postulate that IVR tapped into different learning areas and helped students achieve a number of outcomes such as developing technical skills and becoming autonomous learners, capable of identifying and employing varied techniques, procedures, and resources to create a new articulation of art.

The Table below provides an insight into some KLAs including both STEM and non-STEM areas where the integration of IVR can contribute to achievement of syllabus outcomes. The Learning Challenges created by the stem.T4L Education Team for IVR (e.g. a place of my own, Excursion 360°), available on stem.T4L Learning Library, lend further insights about how use of IVR equipment can integrate the syllabus into classrooms.

| Syllabus | Outcome | Stage |
|---|---|---|
| **Visual Arts** | 4.9 Begins to acknowledge that art can be interpreted from different points of view<br>5.1 Develops range and autonomy in selecting and applying visual arts conventions and procedures to make artworks<br>5.4 Investigates the world as a source of ideas, concepts and subject matter in the visual arts<br>5.6 Demonstrates developing technical accomplishment and refinement in making artworks<br>LS.2 Explores a variety of materials, techniques and processes<br>LS.7 Explores how ideas and interests in the world can be represented in their art-making<br>LS.9 Uses a range of materials, techniques and processes to make artworks | 4 & 5 |
| **Photographic and Digital Media** | 5.5 makes informed choices to develop and extend concepts and<br>different meanings in their photographic and digital works<br>5.6 Selects appropriate procedures and techniques to make and<br>refine photographic and digital works<br>LS.3 Explores the function of photographic and digital artists and how they work<br>LS.5 Recognises that various interpretations of photographic and digital works are possible<br>LS.4 Explores ways in which experiences of the world can be communicated in photographic and digital works | 4 & 5 |
| **Technology Mandatory** | TE4-10TS Explains how people in technology related professions contribute to society now and into the future<br>TE4-1DP Designs, communicates and evaluates innovative ideas and creative solutions to authentic problems or opportunities | 4 |
| **Digital Technologies** | ST3-2DP-T Plans and uses materials, tools and equipment to develop solutions for a need of opportunity | 3 |
| **Working Scientifically** | ACSIS093, ACSIS110 Communicate ideas, explanations and processes, using scientific representations including multimodal forms | 3 |

*Table 5. IVR's links to KLAs*

# CONCLUDING REMARKS

Although the quantitative data collected through pre-post surveys indicated no significant difference in technology-related variables between before and after the completion of the Masterclass, the qualitative data, as explained above, suggested a significantly positive impact of the learning environment equipped with stem.T4L technology on girls' learning and engagement. This impact was particularly powerful in raising girls' awareness of and appreciation for technology in the art world that further motivated them to explore the potential of technology in contemporary society more broadly.

At the conclusion of this study, we would like to highlight that the after-school Masterclass and the project-based instruction implemented in that environment played a major part in realising the full potential of stem.T4L for girls. The effective and constant use of IVR, which was aimed at creating a real-world product, and the ample opportunities that existed for hands-on and collaborative learning, without a doubt created an ideal context for students to engage with stem.T4L. In such an environment, students had the opportunity to see themselves as a young team of experts in the field of technology, capable of designing, exploring, and solving technical problems together. We recommend that to encourage girls' participation in STEM fields and to boost their sense of confidence in using technology, schools establish informal and positive learning environments where girls individually and collectively explore diverse aspects of STEM technology, observe their impacts first-hand, and practice creativity to produce tangible products and experiences. The more positive girls' experiences are in utilising technology to create outcomes that impact the real world, the higher their likelihood to persist in STEM fields.

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