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A novel approach to mapping changes in student attitudes towards science and mathematics in reaction to changes to their learning environment

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Abbreviations

ANOVA	Analysis of Variance
CAP	Composite Attitude Profile
CAR	Composite Attitude Rating
IQR	Inter-quartile Range
KLA	Key Learning Area
NESB	Non-English Speaking Background
OECD	Organisation for Economic Co-operation and Development
SACE	South Australian Certificate of Education
SAP	Subject Attitude Profile
SAR	Subject Attitude Rating
SAS	School Attitude Survey
SES	Socioeconomic Status
STEM	Science, Technology, Engineering and Mathematics
TELE	Technology Enhanced Learning Environment
TICS	The Innovation and Creativity School

Executive summary

This project set out with the intent of exploring the potential of an innovative research method for use in the evaluation of university outreach programs in the science, technology, engineering and mathematics (STEM) fields. The disruptions caused by the COVID-19 pandemic and the suspension of the targeted programs early in the project changed the target application somewhat, but not the overall purpose of the project. Applied instead to an in-house STEM program at a partner school and the move to online learning due to the suspension of face-to-face teaching due to the pandemic, the central research question for the project remained: “Can novel research methods provide access to useful and usable evaluative data on student attitudes towards their school subjects particularly in response to changes in their learning program?”

This is an important question in the context of student equity in higher education. Many programs and interventions seeking to improve equitable participation in higher education — such as STEM outreach programs — do so by seeking to impact not only the skill development of young people, but also attitudes towards further study. Our capacity to understand changes in attitudinal factors, however, has been quite limited outside of large-scale research projects. The purpose of this project has been to address this data gap through the development of a “light touch” data collection tool and the demonstration of the kinds of knowledge that such tools can provide.

The initial answer to our research to this question is “yes” — although clearly more research is needed. The report that follows will elaborate on this answer and detail our use of a light-touch or micro-survey instrument to unobtrusively collect frequent information on changes to a number of attitude constructs among students in two large Australian schools. The report is presented as three case studies that will inform both potential end-users and those with aligned research interests of the approach.

The first case study sets the scene. Noting the importance of student attitudes towards STEM, this study shows how a picture can be developed on how students’ attitudes towards STEM subjects vary between students in different year groups at the same school. This was a pilot study carried out in one year, so the picture presented in this case study is not longitudinal. Never-the-less, the cross-sectional findings suggest a developmental trajectory that can be further explored. This is important to know when planning interventions seeking to affect student attitude and identity formation as a means of encouraging equitable participation in higher education.

The second case study was opportunistic and stepped away from our primary interest in STEM pathways to higher education. It considered the impact of an unexpected move to online-mediated distance learning caused by COVID-19 and compared students’ attitudes to learning for Science and Mathematics at two schools with very different experiences of the pandemic. In doing so, the study demonstrates a different potential use for the kinds of methods being used in the project — a use that is highly relevant to those interested in supporting participation in higher education by those who may have fewer resources to deal with disruption, be it at a global or personal level.

The final case study is essentially what we intended for this project before the onset of COVID-19. Due to the limitations of the pandemic, the school provided its own ‘outreach’ program in the form of incursions to a new dedicated facility known as ‘The Creativity and Innovation School’. In this case study we looked at how the data collection and evaluation methods we have been developing work to evaluate the impact of a week-long STEM experience for Year 7 students.

The three case studies have allowed us to make the following seven recommendations.

Recommendation 1: Programs that aim to develop awareness of specific career pathways should be designed to appeal towards students in the early years of secondary school, or possibly earlier.

Recommendation 2: Programs that aim to develop positive attitudes towards school subjects should attempt to demonstrate the usefulness of subject content knowledge across a wide range of potential careers and also non-vocational contexts.

In case study 1 we show that for many attitudinal factors the range of attitude ratings increases as the age of students increases until the end of the middle years of secondary school before becoming narrower again by Year 12. While longitudinal studies will be needed, this pattern was strongly evident in both schools in this study suggesting a common developmental pattern.

Of particular interest for programs aiming to develop specific career awareness is that students' reported *Intentions* to continue to study their school subjects decreased across year groups as the students' age increased. Considering data from all three case studies, we conclude that by mid to late secondary school students have formed ideas of which career pathways may or may not be suitable for them and they are expressing their *Intentions* towards their school subjects through this lens. Therefore, it appears to be important to develop programs that emphasise the applicability and transferability of subject specific skills and knowledge to many possible career paths and to other uses in life when designing and implementing programs aimed at younger students.

Recommendation 3: Programs that seek to impact students' attitudes towards school subjects should be domain (discipline) specific in focus.

We show in case study 1 and 2 that students' attitudes towards Mathematics and Science are quite different to each other. This finding, that students hold different attitudes towards the different domains of their curriculum, suggests that a one-size-fits-all approach to designing learning programs does not exist across the different domains, and that any potential outreach programs may need to be domain specific or focused in terms of their learning objectives. This finding may be particularly important when considering programs in cross-curricular areas such as "STEM".

Recommendation 4: Outreach activities with the aim of increasing participation in Science might be most successful if they are implemented for students around 13 to 15-years-old and address both *Usefulness* and *Enjoyability* in their design.

Recommendation 5: Programs that target older students' participation in Mathematics should focus on communicating the relevance and interesting applications of the subject.

The baseline data of case study 1 provides important guidance for programs seeking to improve participation and success in higher education. It tells us that in gateway subjects like Science, young people are making important decisions on their career pathway by around 15 years of age, and that these decisions do have an impact on their ongoing attitude to different areas of study. These students' decisions are associated with a decline in *Enjoyability*, which is strongly associated with *Self-efficacy*. While it is difficult to construct causal models from the data at this stage, the associations can be considered in terms of identity. That is, we are seeing that there is a significant group of young people who, no later than Year 9, have decided that they are not good at Science, that they do not enjoy Science, and that Science has no use in their career future.

Notably, the data also indicate that Mathematics *Anxiety* steadily increased between cohorts as the students became older but that the perception of *Difficulty* followed a more variable pattern. The overall pattern seems to suggest that students have heard the popular message that Mathematics is important for many future careers and that they *should* continue to study the subject at school. Yet, as students become older, they find the subject increasingly less interesting, less relevant, and an increasing challenge to persevere with. It is therefore important that programs that target older students' participation in Mathematics should place a special focus on communicating the relevance and interesting applications of the subject to the students.

Recommendation 6: Programs that aim to impact students' attitudes of Enjoyability, Relevance and Self-efficacy should consider using *Creativity* as a driving principle during the educational design.

The triplet of attitudes *Enjoyability, Relevance* and *Self-efficacy* were seen to strongly correlate with each other across multiple subject areas, and across both schools. In each case, this triplet of attitudes was seen to also correlate strongly with *Creativity*, a factor we measured separately. This is particularly interesting because while the triplet of attitudes measures value-based or perceived attitudinal constructs, our Creativity construct was action based. That is, creativity as defined and described in the Introduction to this report is a teachable skill and a practical approach to learning. Therefore, C*reativity* may have some potential to be a mechanism to affect the positive changes in students' attitudes towards their school subjects as discussed earlier and may, in turn, be able to assist in reducing subject *Anxiety* and students' perceptions of relative *Difficulty*.

Recommendation 7: Short duration programs need to be highly focussed if they are to have a measurable effect on student attitudes.

In case study 3 we found no statistically significant change in underlying student attitudes towards Science or Mathematics after a one-week program in the technology enabled learning environment, TICS. The students engaged in four or five classes for just a few hours each, essentially sampling from the smorgasbord of activities available to them. The program as implemented by the teachers at Corroboree Frog College was not designed to focus on one specific skill, application or problem but was instead designed to expose students to a breadth of STEM skills. Future programs could benefit from this experience by remaining tightly focussed at the educational design stage if they are to have a specific and measurable impact on student attitudes.

Introduction

The perceived need to improve the attitudes of young people towards science and mathematics, and hence to improve participation in higher education in these fields both in absolute and in equity terms, is longstanding. In the mid-twentieth century, at the height of the space race, it spawned an entirely new kind of museum beginning with San Francisco's *Exploratorium* and represented in Australia by centres such as *Questacon* in Canberra (Leonard et al., 2017). Today this need continues under the banner of 'Science, Technology, Engineering and Mathematics or "STEM". A consistent theme in global policy — education policy but other areas such as industry policy as well — is a need to improve attitudes towards STEM and participation in STEM. In Australia, for example, the Chief Scientist has called for the country to become a 'science nation' (Office of the Chief Scientist, 2014b) and has developed an index of the literally thousands of programs that seek to do so (Office of the Chief Scientist, 2016a).

Programs seeking to improve attitudes and to open up the pathways towards studying Science and Mathematics at the higher education level are the focus of significant investment. They are among the most prominent of the higher education equity pathway programs in Australia. Among the thousands of programs listed above, for example, is the STEM outreach program at the authors' own university (https://study.unisa.edu.au/unisa-connect/). This program receives millions of dollars each year to provide informal educational opportunities that explicitly seek to improve the attitude towards and interest in STEM for young people in the lower socio-economic areas of our city, students from regional areas of our state, girls, and Aboriginal students.

Despite this ongoing policy interest and intense investment, attitude is actually poorly understood, and the capacity to measure or evaluate the impact of different programs on the attitudes of young people has been quite limited. As we will discuss in this report, 'attitude' is a concept bringing together many constructs such as interest and perceived usefulness, but also self-efficacy and difficulty. This is a complex space that is poorly explored through common program evaluation questions such as "are you more likely to study STEM subjects in the future" or "are you more likely to pursue a STEM career".

This project has sought to explore the use of new tools emerging from research in the learning sciences to provide near-real-time data that is useful in real world implementation — as opposed to the typically better resourced conditions found in a research project — when exploring complex and multifaceted matters such as program impact on attitude. Education is complex, and we seeking to develop new evaluative tools that can embrace this complexity and provide appropriate feedback to those designing and implementing programs aimed at improving participation in higher education pathways.

In schooling, our assessment has been traditionally directed towards the measurement of knowledge and, to a lesser extent, skill development. Less attention has been paid to attitudinal development. Put simply, while research provides some evidence on the question of students' attitudes, in real-time program operation and evaluation in schools we have an underdeveloped capacity to know when attitudes towards different subjects are changing, or how frequently and/or strong those changes are. This makes it very difficult to discern what might be the primary causal factors in relation to attitudinal development and how we might respond effectively.

To an extent, the challenge of evaluating educational programs has been somewhat alleviated by the sheer difficulty in adequately measuring many of the things we might most like to know about a program. Outside of the confines of a well-funded and well-staffed research project, it has been difficult to capture the impact of an educational program on factors such as how a young person's attitude towards a particular subject might change over time in response to the program, or how the program might bolster their capacity to leverage their social network when problem solving. Recent advances in information and communications technology, and also in educational research methods emerging from fields such as the learning sciences and learning analytics, however, may change this (Leonard et al., 2016). Together, technological and methodological innovations are allowing for a much more efficient collection of relevant data on a much greater range of factors, supporting the analysis of that data in timeframes that are useful for 'real-time' formative evolution as well as for the longer timeframes associated with research and evaluation. Many of these advances have occurred in the context of digitally mediated higher education where much of the data collection can be automated. This project sought to investigate the use of such approaches in the 'messier' world of regular secondary schooling.

This pilot project sought to address this gap and to explore how emerging technologies and methodologies from the *learning sciences* might facilitate near real-time data collection on changes in students' attitudes towards their school subjects. In the original design of the project, we proposed to investigate if we could "measure" if the STEM outreach programs offered to schools by our university, the University of South Australia, led to attitudinal or affective change among participants. This is an important question in part because these programs constitute one of the largest recurrent investments made by the University in supporting equitable access to higher education. The disruptions of COVID-19 and the suspension of our outreach programs, however, enabled us to investigate also the self-motivated changes made to learning programs in two of our partner secondary schools. Specifically, we investigated attitudinal changes around the "in-house" use of a new technologically enhanced learning environment, and the move to digitally mediated distance education made as a result of the pandemic.

The primary method for measuring changes in attitude and affect explored in this project was the use of a micro-survey tool (Kennedy et al., 2016). The collection tool required students to use a sliding scale on a computer screen or mobile device to indicate their current feelings towards each of their school subjects across an array of attitudinal constructs. The survey required only a few minutes to complete and did not create a major impost on the student or their class time meaning that it was possible to collect data every few weeks. The project also made use of other validated instruments to measure factors such as student self-regulation and anxiety in order to build stronger models of what the self-report data through the micro-survey was telling us.

The report is presented as three case studies through which we hope to inform both potential end-users of the approach as well as those with aligned research interests. The first case study sets the scene. Noting the importance of student attitudes towards STEM, this study shows how a picture—or actually a series of pictures—can be developed on how students' attitudes towards STEM subjects vary between students in different year groups at the same school. This is important to know when planning interventions seeking to affect student attitude and identity formation. The data set used in this study was developed in partnership with a very large and diverse school and provides an important baseline for future work in this space.

The second case study was opportunistic and stepped away from our primary interest in STEM pathways to higher education. It considered the impact of an unexpected move to online-mediated distance learning caused by the COVID-19 pandemic and compared students' attitudes to learning in Science and Mathematics at two very different schools.

The final case study is essentially what we intended for this project before the onset of COVID-19, albeit the school provided its own 'outreach' program in the form of excursions to a new dedicated facility known as 'The Creativity and Innovation School' (TICS). In this case study we look at how the data collection and evaluation methods we have been developing work to evaluate the impact of a week-long STEM experience for Year 7 students at TICS.

As this report shows, the revised project has demonstrated that it is possible to generate a rich and near real-time picture of changes in student attitudes from this data collection. The project generated a number of significant findings in relation to the case studies, including observations that:

- Students hold generally positive attitudes about school even in the face of the uncertainty surrounding COVID-19.
- Year 11 and 12 students reported being more anxious about Science, found the subject more difficult and had lower self-efficacy towards it than their other subjects.
- Year 11 and 12 students reported having more negative attitudes towards mathematics than their other subjects across multiple attitudinal factors.
- Students' attitudes across the different attitude constructs measured within each specific school subject are inter-dependent and not independent.
- Students' ratings of *Enjoyability*, subject *Relevance* and *Self-efficacy* are strongly correlated with each other across different domains and that the teachable attitude of *Creativity* correlates well with these.
- There appears to be a "decision point" regarding students' attitudes towards the utility of studying Science towards the end of Year 8 or early in Year 9. If there is a similar "decision point" for Mathematics then this appears to occur at a much younger age.
- Differences between how the normal school curriculum is delivered at different school campuses appear to have a greater impact on student attitudes towards mathematics than a week-long incursion at a technologically enhanced learning environment TELE.

Background

In recent years there has been a notable policy discourse centred around the continuing decline in participation in post-compulsory STEM courses at both the upper secondary and tertiary levels (e.g., Commonwealth of Australia, 2015b; Lowe, 2014; Office of the Chief Scientist, 2013; Prinsley & Baranyai, 2015). At the same time, the STEM disciplines have been identified as the "new driving force" for the Australian economy in the coming decades (e.g., Commonwealth of Australia, 2015a; Economics, 2014) and much has been made of the need to produce more STEM-skilled students in Australian high-schools (e.g., Education Council, 2015; Office of the Chief Scientist, 2014a, 2016b; Prinsley & Baranyai, 2015).

Outreach work by universities in relation to promoting STEM has been one clear policy response from government. This draws on a long tradition of such efforts, with outreach programs that parallel or augment the formal education system dating back to at least the 1960s (Leonard et al., 2017; Ogawa et al., 2009; Pedretti, 2002). These programs have often had the dual objectives of increasing and diversifying participation in scientific educational and career pathways as well as broadening public capacity to engage in socio-scientific decision making (Collins & Pinch, 1993) within a democracy. The STEM agenda of recent years has seen a new wave of investment in these programs and has included many programs offered directly by businesses and industry bodies seeking to ensure an increase in the supply of workers with STEM skills.

Figure 1. Students program a Sphero™ robot using a mobile device.

In Australia alone — across government, industry, and universities — the cost of the investment into these programs runs into the hundreds of millions of dollars each year (Office of the Chief Scientist, 2016b) and they represent one of the major focal points for efforts to increase the participation in higher education by equity groups. Many of these programs are designed on an ad hoc basis and the design of STEM outreach programs has become quite diverse, ranging from simple talks by STEM professionals, to short experiences of scientific phenomena (e.g., a chemistry show), to extended and complex challenges (e.g., NASA's Epic Challenge program). The common thread running through many of these programs is the link between students' personal attitudes on the one hand, and their educational choices and career trajectories on the other.

The interaction between students' attitude towards Science and their future educational and career intentions has been of interest to researchers in science education for at least half a century now. This work has shown some clear patterns that seem to persist over time and across national boundaries such as a common decline in attitude towards Science in the first few years of secondary schooling (e.g., Gardner, 1975; Ormerod & Duckworth, 1975; Osborne et al., 2003; Osborne et al., 2009; Potvin & Hasni, 2014; Simpson & Oliver, 1985, 1990; Sjøberg & Schreiner, 2010).

With respect to students' educational choices and career trajectories, the research provides clear evidence of a link between attitude and enrolment intention (for extended reviews see, for example, Gardner, 1975; Kennedy et al., 2018; Ormerod & Duckworth, 1975; Osborne et al., 2003; Osborne et al., 2009; Potvin & Hasni, 2014; Simpson & Oliver, 1985, 1990). In their recent contribution to this corpus, Summers and Abd-El-Khalick (2019) reported that students' intrinsic variables—particularly their self-perception of science ability and science-related talk with family members—appeared more effective in predicting student intention than group level factors such as teacher practice.

While the link between positive attitudes towards STEM subjects and engagement with classroom learning in the four STEM areas is therefore strong, the ability of STEM outreach programs to impact student attitudes is less so. A significant number of STEM outreach programs focus on the use of divergent thinking and the power of creativity in their delivery as a method of increasing student engagement. This often flows naturally from the task focussed and problem-solving nature of the activities and is done in an effort to develop positive attitudes towards STEM in students.

Figure 2. School students analyse experimental data in the university laboratory.

The vast majority of STEM outreach programs report receiving highly positive evaluations in terms of reported student experience, yet the effectiveness or the programs in achieving their goals of increasing diverse participation in STEM career pathways or socio-scientific decision-making (see for example Bencze et al., 2011) is less clear. It is notable that despite at least half a century of significant effort in STEM outreach, significant gaps in workforce participation in the core STEM areas remain particularly among women, people from low SES backgrounds, Indigenous Australians, and people from rural areas. At the same time, the research literature is dominated by projects focussed on the student experience of individual outreach activities and little has been done to investigate ongoing impact or to understand the principles of effective program design.

Given this, the project initially aimed to investigate the effect of STEM outreach programs on students' attitudes towards STEM subjects in schools and their intentions towards STEM courses in post-compulsory education. Unfortunately, the onset of the COVID-19 pandemic saw the majority of outreach programs cease operation during the second and third school terms of 2020. At the same time, the COVID-19 pandemic also imposed constraints on in-school learning and teaching with students in all areas of Australia experiencing some restrictions on their learning experiences. With the restrictions increasing the need for individual student agency, independence, and creativity, could the changing approaches to learning act as a catalyst for developing positive attitudes towards STEM and other areas? In response, this project's design was adjusted slightly to include investigating the concept of learning creativity alongside the other student attitudes.

Measuring attitudes

Research into attitudes has sought a coherent, consistent, and non-commutable working definition for the concept with varying degrees of success (Blackley & Howell, 2015; Blalock et al., 2008; Osborne et al., 2003). Kind et al. (2007, p. 873) attempted to address the confusion and defined an attitude as "the feelings that a person has about an object, based on their beliefs about that object". This is the definition of attitude used in this research where the *object* considered was the school STEM courses studied by the students. While we have adopted this definition, we acknowledge that it is not universally accepted, and that the absence of a shared definition simply reflects the complexity of this space and that the concept of "attitude" cannot be seen as a simple construct.

Reflecting the diverse influences on 'attitude', the School Attitude Survey (SAS) instrument used in this study approaches attitude as a multidimensional array of linked constructs. Rather than generate a single attitude *score*, it seeks to generate a mosaic-like attitude profile for various aspects of a student's school experiences and thence put the parts together to provide an overall picture. The SAS measures a student's attitudes or perceptions towards their subjects against nine attitudinal factors:

- subject anxiety
- creativity
- perceived difficulty
- enjoyability
- intentions
- subject relevance
- self-efficacy
- career usefulness
- personal usefulness.

Figure 3. Measuring attitudes

Influencing attitudes: the potential for creativity

Creativity is a broad term used in everyday parlance to indicate the ability to create new ideas or products that transcend traditional rules, patterns, or relationships. Given our everyday usage of the term it would be easy to assume that there is little consensus on the definition of creativity in education. Yet there is actually widespread agreement on core concepts (Cropley, 2015). From early investigations (see, for example, Barron, 1955; Guilford, 1950) to modern conceptions (see Diedrich et al., 2015; Kaufman, 2016), definitions of creativity have had two essential components.

Creativity firstly involves originality or novelty, and secondly must also involve task appropriateness. In this formulation, something is creative if it is new *and* it is useful for its desired purpose (Simonton, 2012).

The importance of developing and building complex competencies, including that of creativity, through education has become a staple of global education policy development. The Organisation for Economic Co-operation and Development (OECD), for instance, has highlighted the significance of creativity in its work on the “transformative competencies” needed from education in the twenty-first century (OECD, 2019). The best ways to develop competencies such as creativity within formal education, however, remain a matter of intense research interest (Vincent-Lancrin et al., 2019) and debate (Cropley & Patston, 2019).

However, it has been established that creativity can be a teachable and learnable skill within schools (for a meta-analysis see Scott et al., 2004). It is for this reason that it has been included in many global curricula as an essential twenty-first century skill (Kupers et al., 2019). Many informal and formal STEM outreach programs also utilise an approach embracing creativity in an effort to develop positive attitudes towards STEM in students. While the students undoubtedly enjoy these outreach programs, there is little research indicating clearly if developing positive attitudes of *Creativity* to learning has the desired effect of developing positive attitudes towards STEM subjects.

The partnering schools

Two co-educational schools partnered with the University of South Australia in the case studies presented in this report. These schools are very different institutions (see Figure 4), both before and during the COVID-19 pandemic.

The first school, which we will refer to as Corroboree Frog College, is a non-academically selective day student only school spread over five campuses and located in South Australia. The school attracts students from a wide socioeconomic background with around two-thirds of the students at the school coming from households within the middle two quartiles of the Australian socioeconomic status (SES) distribution. The school has approximately 3600 enrolments with around 2% of students coming from an Indigenous background and 11% of students coming from a non-English speaking background (NESB). Typically, around 60 to 70% of students progress to university.

The second school in the study, which we refer to as Green Tree Frog School, is predominantly a non-academically selective, single campus, boarding school with many students of medium to high SES located in Victoria. The school has approximately 1500 enrolments with around 2% of students coming from an Indigenous background and 25% of students from a NESB background. In general, upwards of 90% of students proceed to higher education.

Students from different year groups at both schools contributed data to this project at various times. More detailed information about the student samples is provided in the respective case studies.

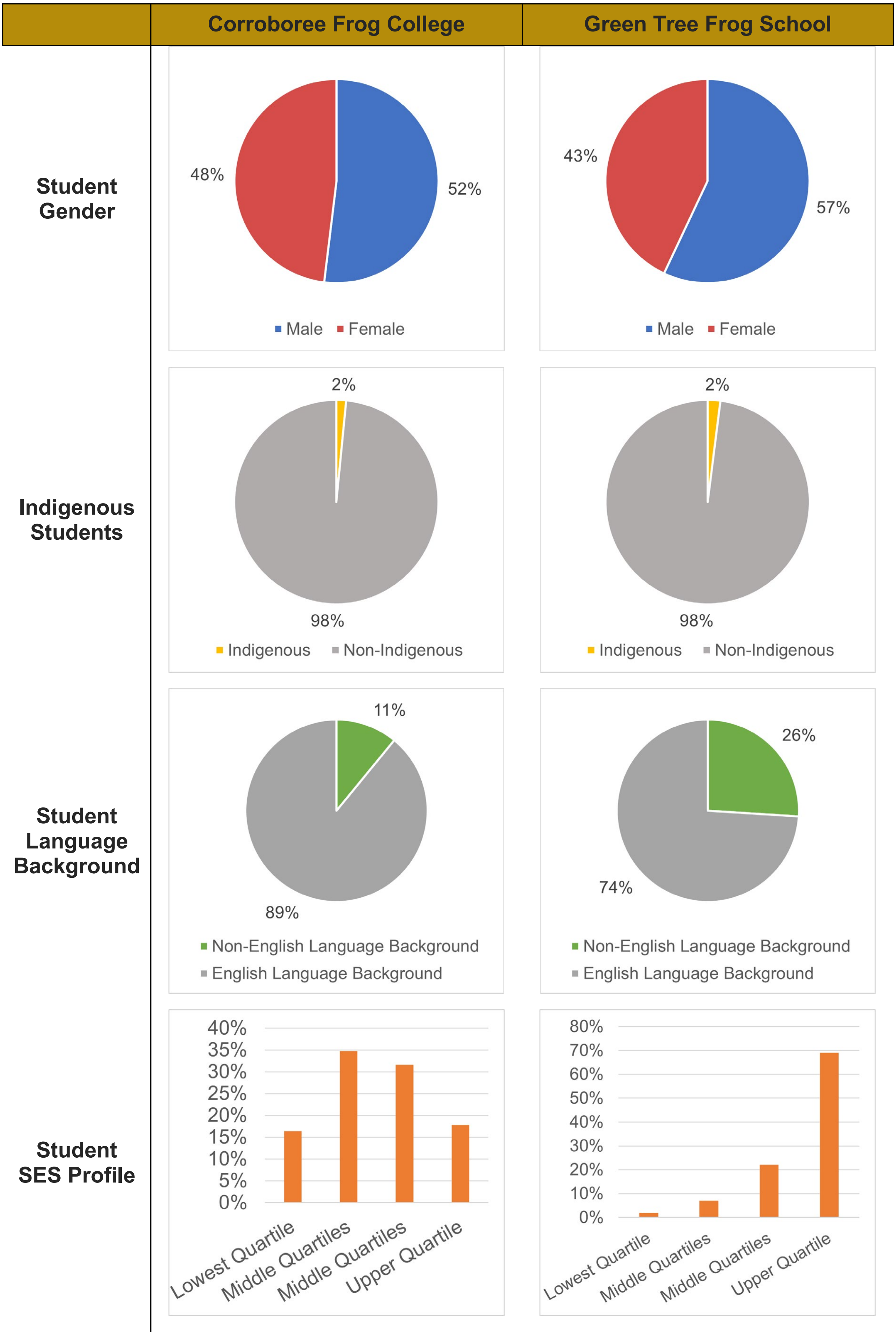

Figure 4. Demographic profiles of the two partnering schools.

Methods

Understanding the impact of any short-term intervention seeking to influence the life choices and interests of young people presents a significant research challenge. The impacts we are seeking are long-term, and the short-term programs are only one among hundreds of factors that have influence. In this context, randomised control trials are neither practical nor necessarily useful. The case-study designs that have dominated the research in this area, on the other hand, may not provide a comparative basis to discern what is most salient in intervention design.

The novelty of our approach lies in its style of data collection. We have built on an instrument outlined by Kennedy et al. (2016) and developed the SAS, a micro-survey offered to students at both Green Tree Frog School and Corrobboree Frog College at various times during Terms 2 and 3 in 2020 (see individual case studies for specific timings). This approach to frequent sampling of attitudinal data has only emerged in recent years with the emergence of mobile devices and has not previously been applied to the STEM outreach space on any scale.

Within the complex context of schooling, it is reasonable to suggest that the distinct aspects of an individual student's attitudes towards their school subjects may develop at different rates and in response to different stimuli for their different subjects. That is to say, a student's attitude with respect to the perceived *Difficulty* of Mathematics is likely to develop at a different rate and in different ways than their attitudes towards the *Personal Usefulness* of a subject like History.

The SAS measures a student's attitudes towards all school subjects using a digital web-based instrument. Students accessed the tool using any internet connected device and move the response sliders to indicate their attitude towards nine constructs (Figure 5 shows a screenshot of the interface). These slider inputs form a visual analogue scale from -50 to +50 and each of the general statements listed in Table 1 is presented on a separate screen.

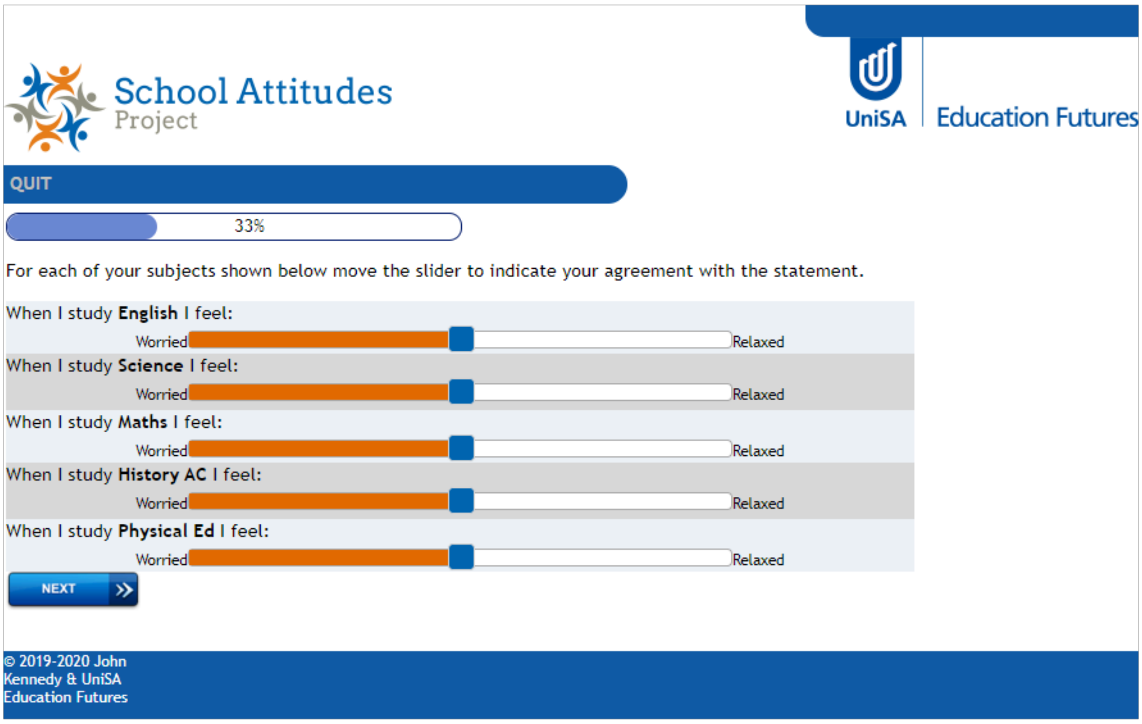

Figure 5. Screenshot of the School Attitudes Survey interface

A student's mean attitude rating for each attitudinal factor across all subjects is calculated and is known as the student's Composite Attitude Rating (CAR). A student's CAR can be thought of as a measure of their average attitude to the academic aspects of school as a whole. Following the approach detailed in Kennedy et al. (2016), Subject Attitude Ratings (SAR) can then be calculated by subtracting a student's CAR for a specific attitudinal factor from their raw attitude rating for the individual subject for that same attitudinal factor. A SAR could therefore theoretically fall in the range -100 to +100. **A student's SAR can be thought of as a measure of their attitudes towards a single subject area in comparison to their attitude towards their schooling experience as a whole.** Table 2 shows the calculation and relationship between raw, composite, and subject attitude ratings for a hypothetical student studying only three subjects.

Table 1. Item wording for each of the Attitudinal Factors in the School Attitudes Survey[1]

Attitudinal Factor	Item Wording	Left Hand Indicator	Right Hand Indicator
Subject Anxiety[2]	When I study <SUBJECT> I feel:	Worried	Relaxed
Creativity	When I study <SUBJECT> I am able to develop new and useful ways of independent learning	Strongly Disagree	Strongly Agree
Difficulty[2]	I struggle with completing the assignments for <SUBJECT> class.	Strongly Disagree	Strongly Agree
Enjoyability	I think <SUBJECT> is:	Boring	Enjoyable
Self-Efficacy	I think I am very good at <SUBJECT>	Strongly Disagree	Strongly Agree
Career Usefulness	A job as a <OCCUPATION> would be interesting.	Strongly Disagree	Strongly Agree
Personal Usefulness	For my planned career, knowledge of school <SUBJECT> will be:	Worthless	Priceless
Relevance	<SUBJECT> helps to make life better.	Strongly Disagree	Strongly Agree
Intentions[3]	I am very likely to enrol on a <SUBJECT> course in Year 11. I am very likely to enrol on a <SUBJECT> course after school	Strongly Disagree	Strongly Agree

Table 2. Hypothetical conversion of participant's raw attitude ratings into composite and subject attitude ratings for a partial attitudinal profile

Attitudinal Factor	Subject Raw Rating				Composite Attitude Rating	Subject Attitude Rating			
	English	Science	Maths	…		English	Science	Maths	…
Subject Anxiety	+20	+10	+15	…	+15.0	+5.0	-5.0	0.0	…
Creativity	+30	-10	+20	…	+13.3	+16.7	-23.3	+6.7	…
Difficulty	-20	+10	-10	…	-6.7	-13.3	+16.7	-3.3	…

[1] The placeholders <SUBJECT> and <OCCUPATION> are replaced at run-time with the participant's actual subject names or an appropriate occupation that that subject might reasonably lead towards.

[2] These items are reverse keyed in the analyses.

[3] Only one of these item wordings is displayed to the student depending on whether they are a Year 10 student (upper wording) or a Year 11 or 12 student (lower wording)

The SAS data are best analysed using a graphical approach in the form of attitudinal profiles. A composite attitude profile (CAP) (Figure 6) for a sample group of students shows the mean values and standard deviations for each of the nine attitudinal factors as calculated across all of the students' courses. The *Anxiety* and *Difficulty* attitudinal factors are both reverse keyed, such that across all attitudinal factors a positive rating represents a ***desired*** outcome.

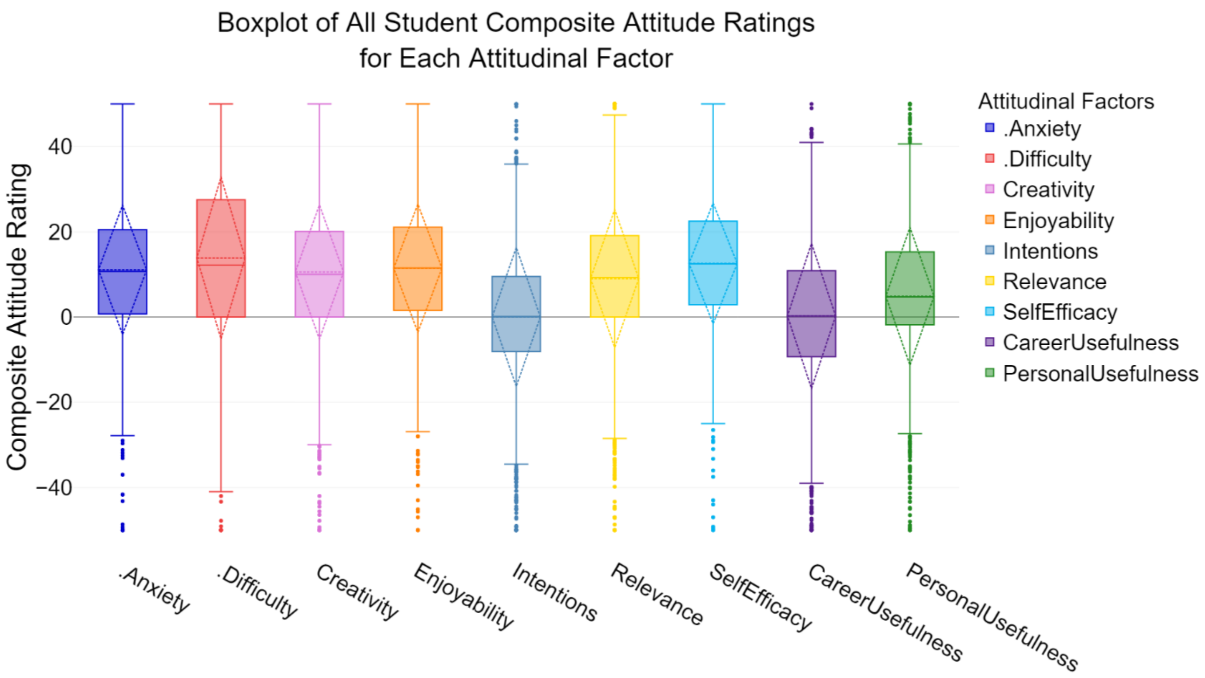

Figure 6. Sample Composite Attitude Profile for all students

The box indicates the interquartile range (the middle 50% of students), the solid horizontal line indicates the median, and the whiskers indicate the lesser of the extreme rating or 1.5 times the interquartile range. Superimposed on the profile is a dotted diamond that indicates the extents of the standard deviation and the position of the mean composite attitude rating.

The same data can be presented grouped by factors such as student year group, student sex, school, or school campus. Figure 7 show the same CAP as Figure 6 but grouped by male and female students.

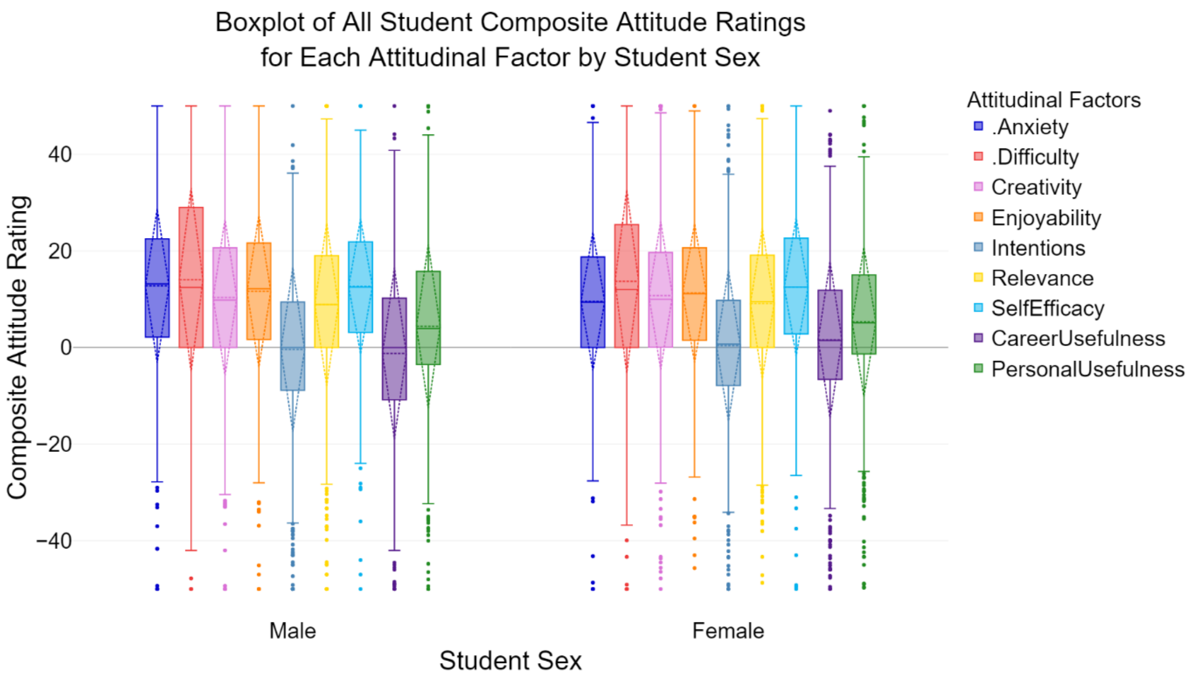

Figure 7. Composite Attitude Profile for all students grouped by student sex

This approach to attitudes allows for highly nuanced findings. In a previous study (Kennedy et al., 2018), for example, it was shown that among a sample of Australian Year 7 high-school students (age 12-13 years old), attitudes towards science remained stable throughout the first year of high-school in many aspects and even increased slightly with regards to *Enjoyability*. However, it was also noted that for female students, *Enjoyability* ratings changed by less than those of their male peers.

Case study one - Student attitudes towards STEM at 'Corroboree Frog' school

This case study presents a synopsis of data collected during late-Term 2 and early-Term 3 2020 using the SAS. The sample in this collection wave of the SAS totalled 1,546 students from Years 6 to 12. Students in Years 11 and 12 attend a single campus we refer to as Senior, while Years 6 to 10 students attend one of four independent sub-campuses known by the pseudonyms Black, Yellow, Northern and Southern. The sample (Table 3a & b) consisted of both male and female students. For administrative reasons, students in Years 11 and 12 were given the opportunity to provide attitude data in both measurement phases of this study and the data included in the following analyses is the mean of their ratings.

Table 3a. & b. Case study one student sample profile

	Male	Female	Total
Year 6	202	188	390
Year 7	113	30	243
Year 8	50	43	93
Year 9	65	59	124
Year 10	57	88	145
Year 11	116	135	251
Year 12	134	166	300
Totals	**737**	**709**	**1546**

	Black	Yellow	Northern	Southern	Senior
Year 6	74	97	158	61	
Year 7	8	36	140	59	
Year 8	22	2	33	36	
Year 9	48	36	22	18	
Year 10	50	24	38	33	
Year 11					251
Year 12					300
Totals	**202**	**195**	**391**	**207**	**551**

The range of data collected by the SAS represented a good sample of the students in these year groups and appeared to represent students from across the full range of attitude positions.

Composite attitude profiles

Figure 8 shows that in general most students at Corroboree Frog College reported relatively similar, slightly-positive composite attitude ratings across most attitudinal factors. These ratings had roughly similar standard deviations and the whiskers cover a wide range of responses. Notably, students' *Intentions* towards further study in their current subjects as well as their perceptions of the *Usefulness* of these subjects for specific careers were reported as being more neutral than their other attitudes. There were a small number of outliers (represented as dots). These were located predominantly at the lower extremes of some of the attitudinal factors, indicating some outlying students who hold generally negative views of their overall schooling experience.

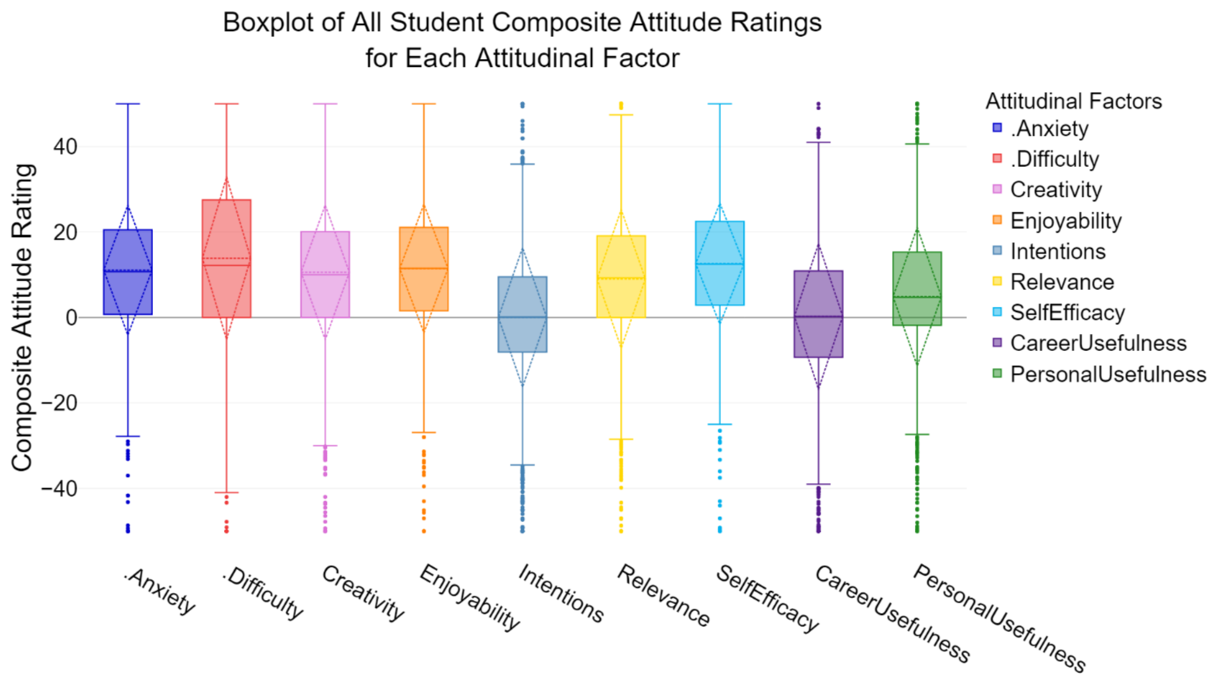

Figure 8. Composite Attitude Profile for all students at Corroboree Frog College
Visit https://schoolattitudes.unisa.edu.au/reports/NCSEHE to view this graph as an interactive.

Figure 8 also shows that students were slightly relaxed (with an *Anxiety* rating above zero) about their learning in general with a mean rating of about +11. However, there were a few students with high levels of subject anxiety present in the sample (represented by the dots at the bottom of the *Anxiety* column).

The neutral ratings for *Intentions* and *Career Usefulness* are likely explained by the curriculum requirement for a student's subject choices to be broad and balanced. This resulted in students reporting positive *Intentions* regarding some of their subjects and negative *Intentions* for others. Similarly, the neutral attitudes towards *Career Usefulness* could be explained by students having a reasonable conception of their future career direction and then being able to judge the usefulness of their subjects in this light.

Figure 9 shows that for many attitudinal factors the range of ratings increases as the age of students increases until the end of the middle years of school (Year 9) and then becomes slightly narrower again by Year 12. Of additional interest is that students' reported *Intentions* to continue to study their school subjects decreased across year groups as the students age increased. The exception to this trend was seen in the Year 9 and 10 cohorts who reported slightly more positive *Intentions* than the year groups either side. Assuming a degree of homogeneity between cohorts, the jump in *Intentions* seen between the Year 8 and 9 cohorts could be interpreted as a consequence of students being able to choose some elective subjects from Year 9 onwards; that is, they are able to elect out of some of the subjects they definitely do not want to study and that they had been reporting very negative attitudes towards in earlier years. The observation that Year 11 and 12 *Intentions* towards further study in school subject areas are lower than the equivalent *Intentions* of Year 10 students could be an indication that students have begun forming a clearer picture of their own future career path and progression and the necessary study pathways to enable this.

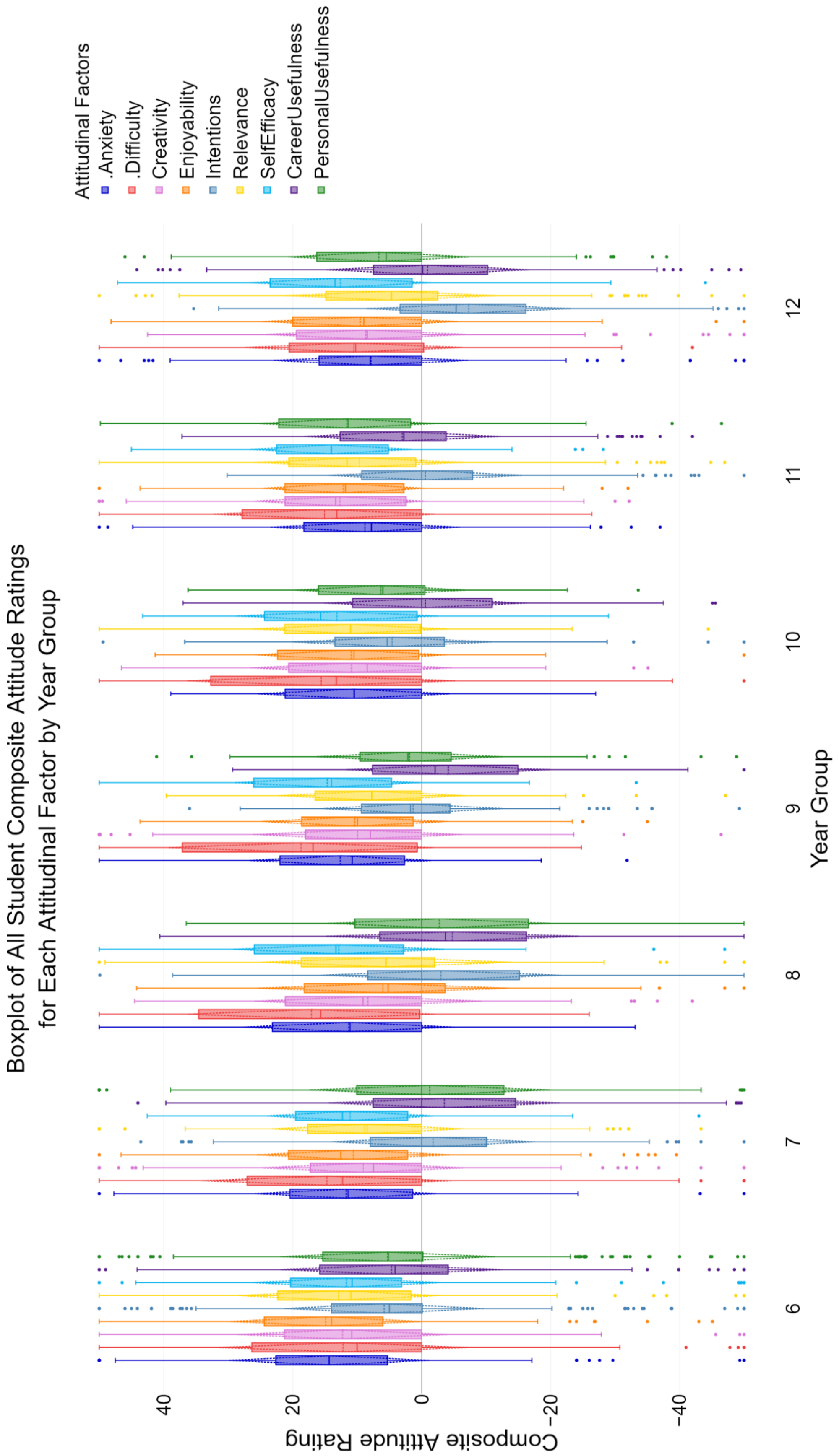

Figure 9. Composite Attitude Profile for all students at Corroboree Frog College grouped by year group
Visit https://schoolattitudes.unisa.edu.au/reports/NCSEHE to view this graph as an interactive.

Restricting the composite attitude profile to consider only *Intentions*, *Enjoyability*, *Relevance* and *Self-Efficacy* shows that across the late primary and early secondary cohorts (Years 6 to 8) students' composite ratings for *Enjoyability* and subject *Relevance* declined along with their *Intentions* to continue to study their subjects (see Figure 10). However, across the senior secondary cohorts (Year 10 to 12) we see that while *Intentions* become more negative, students' ratings for *Enjoyability*, *Relevance* and *Self-Efficacy* do not. This supports the hypothesised explanation for the observed patterns in student *Intentions* described above.

It is also interesting to note that across the late primary and early secondary cohorts' students' ratings on *Self-Efficacy* became steadily more positive while across the older cohorts (Years 9 to 12) ratings of *Self-Efficacy* were relatively comparable. This emphasises the importance of primary school and lower secondary school experiences in forming a positive self-concept and an "I can" attitude.

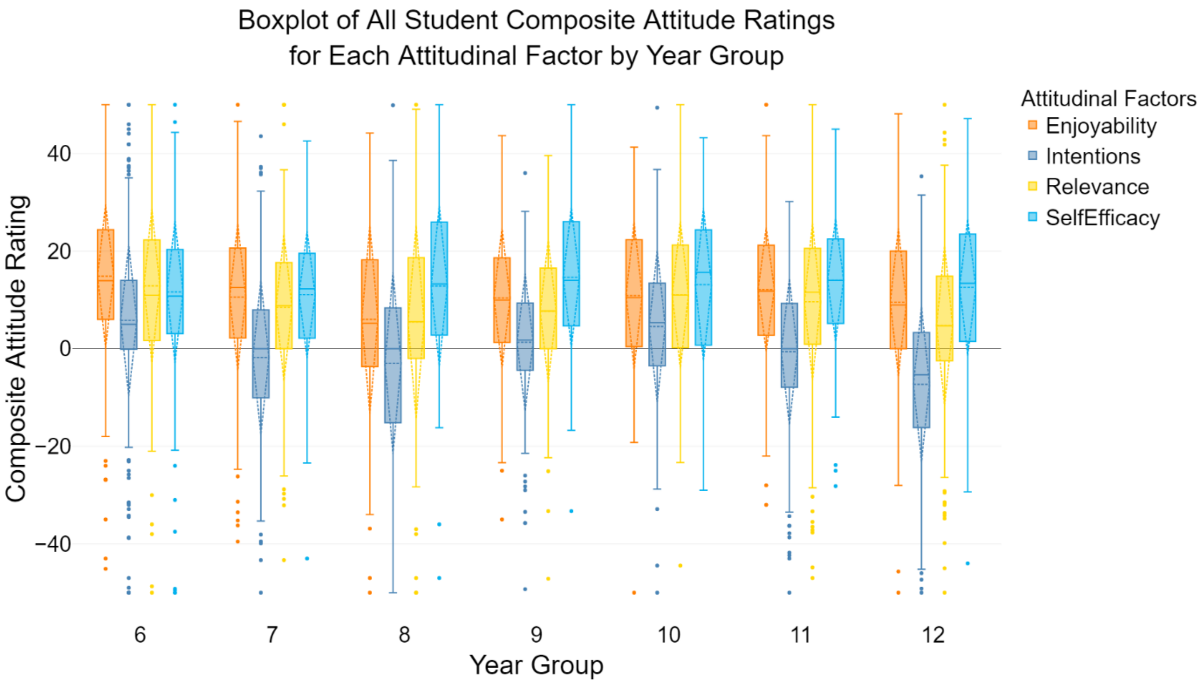

Figure 10. Composite Attitude Profile for all students at Corroboree Frog College grouped by year group showing only selected student attitudes

Figure 11 shows that male and female students held largely identical attitudes towards their academic subjects. However, male students tended to report slightly lower ratings for *Career Usefulness* than female students, while female students reported having slightly higher *Anxiety* about their subjects than their male peers.

Figure 12 shows that the students at the four R-10 campuses had very similar attitudinal profiles towards school in general. Students did not find their work to be too difficult and they indicated that they found their subjects to be enjoyable. However, the Northern campus appeared to have more outliers in student responses—at both extremes—than the other campuses.

Figure 12 shows that the *Intentions* of Year 11 and 12 students attending the Senior campus to continue to study their school subjects into related areas of tertiary education was lower than at the other campuses. However, their ratings of *Personal Usefulness* and *Self-Efficacy* were slightly higher. This lower level of *Intentions* is therefore most likely to be an artefact of the nature of the curriculum than a true pattern in the student's attitudes. That is to say, at this level, the school curriculum continues to mandate a certain amount of breadth, whilst the students are beginning to become more narrowly focussed on their own personal educational path. It is therefore almost inevitable that students will not report positive *Intentions* to all of their school subjects and that composite ratings for *Intentions* will be lower than the younger cohorts.

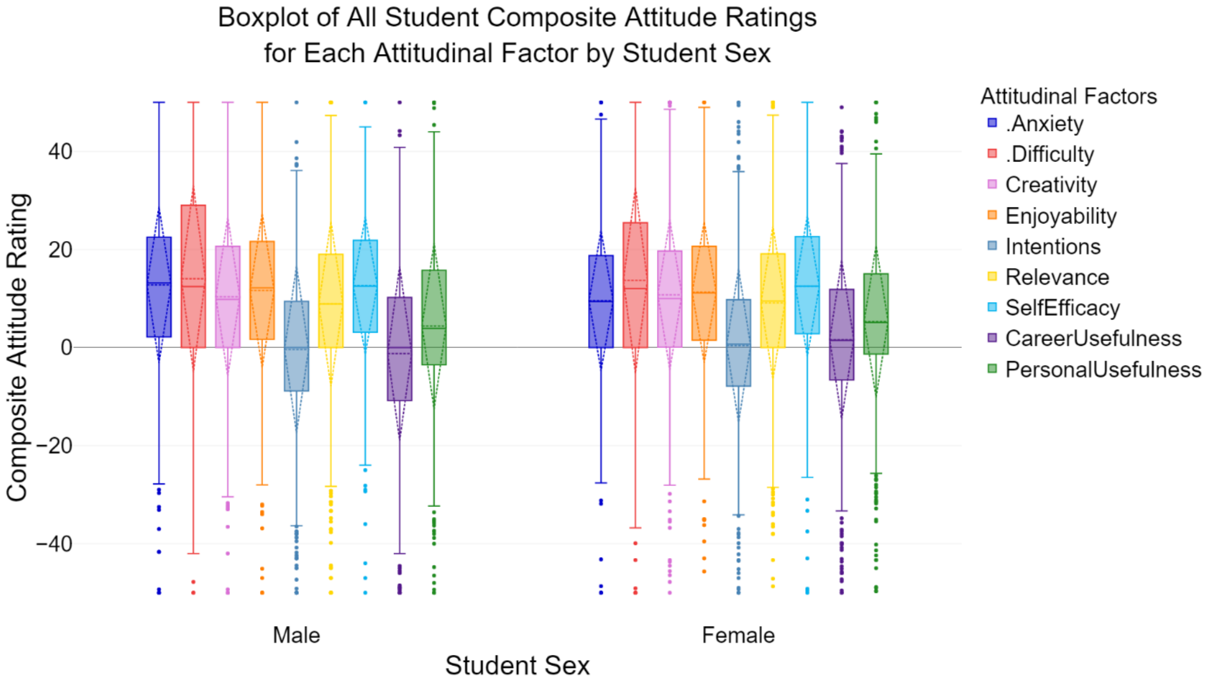

Figure 11. Composite Attitude Profile for all students at Corroboree Frog College grouped by student sex
Visit https://schoolattitudes.unisa.edu.au/reports/NCSEHE to view this graph as an interactive.

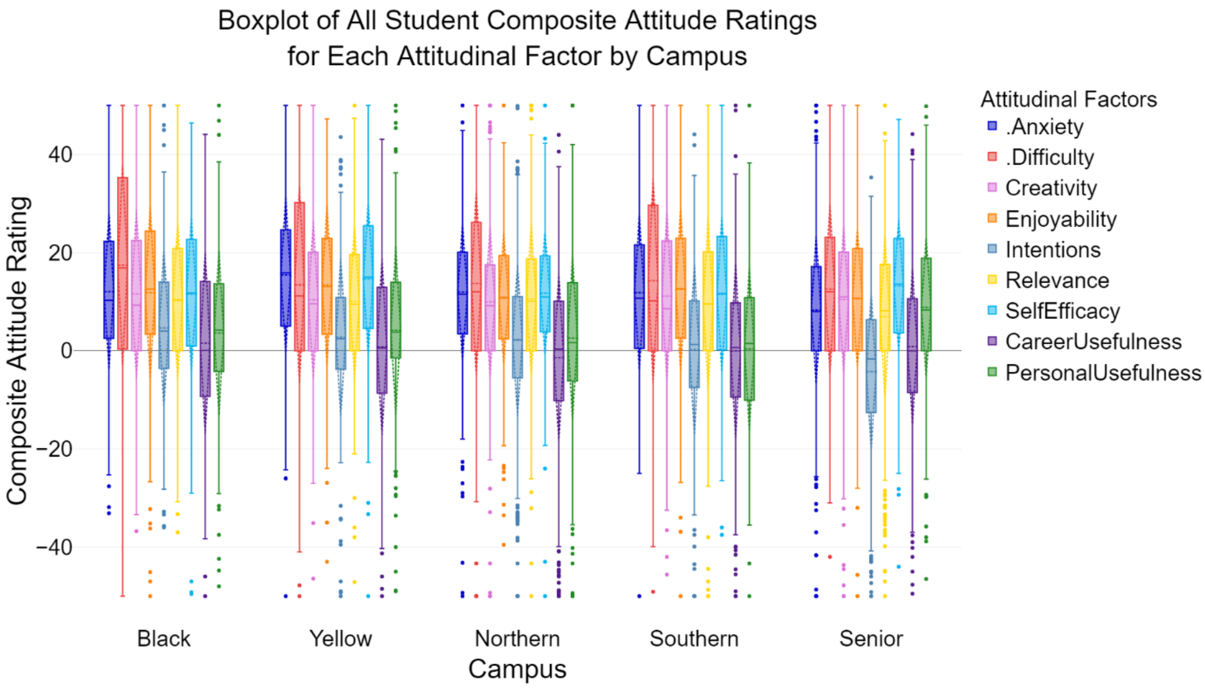

Figure 12. Composite Attitude Profile for all students at Corroboree Frog College grouped by school campus
Visit https://schoolattitudes.unisa.edu.au/reports/NCSEHE to view this graph as an interactive.

Student attitudes towards science

At Corroboree Frog College, all students study a combined Science course in Years 6 to 9 for between 100 (Year 6) to 200 (Year 9) minutes per week. In Year 10 students can continue to study a core Science course or elect to study an extension course in Science. In each case, students are timetabled to study science for 200 minutes per week or 13% of their total class load. In Years 11 and 12 students can choose to study any combination of Biology, Chemistry or Physics or elect to not study any Science subject. Each course is allocated 250 minutes of teaching time per week.

Considering the subject attitude profile (Figure 13) for all students towards Science, it can be seen that students reported slightly higher levels of *Anxiety* (*M* = -5.1, *SD* = 20.2) about Science than their other school subjects and found it slightly more *Difficult* (*M* = -3.3, *SD* = 17.8). However, they held more positive *Intentions* towards further study in Science (*M* = 8.6, *SD* = 26.6) than towards their other subject areas and reported that the content that they learned in Science was more useful than the content they learned in their other subjects both for their *Personal Career* (*M* = 6.3, *SD* = 24.6) and for a career in a scientific area (*M* = 7.9, *SD* = 22.1).

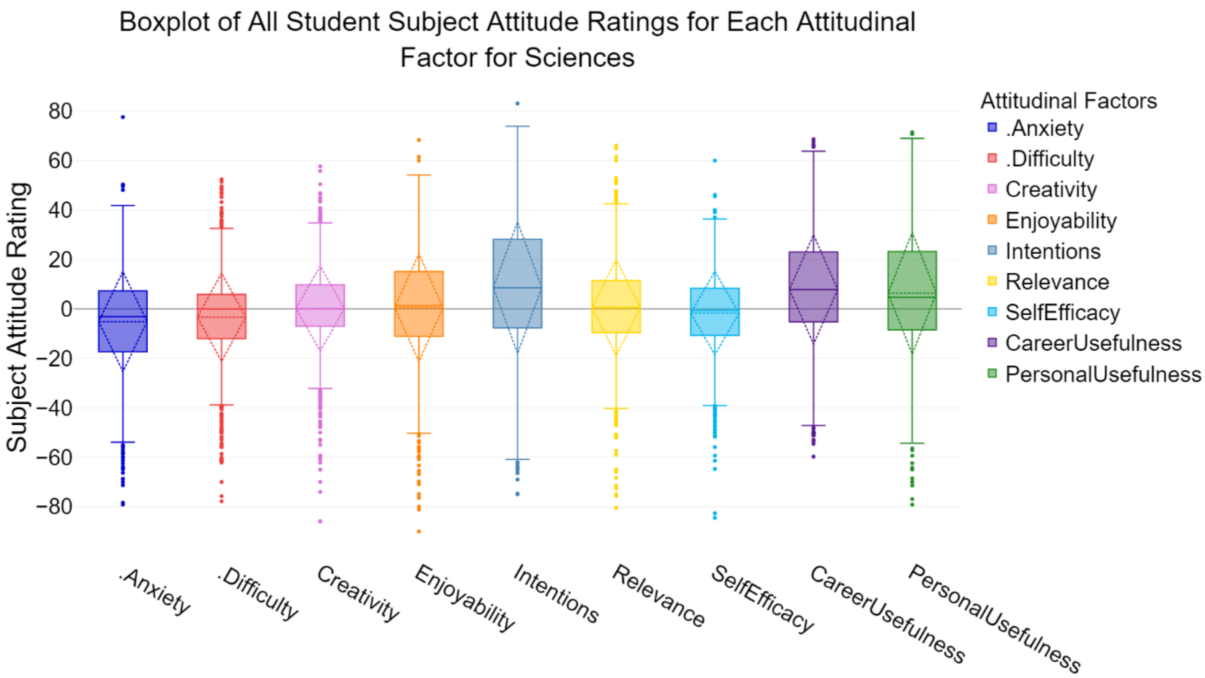

Figure 13. Subject Attitude Profile for Science subjects at Corroboree Frog College for all students
Visit https://schoolattitudes.unisa.edu.au/reports/NCSEHE to view this graph as an interactive.

Figure 14 shows how students' attitudes towards school Science varied between year groups. Year 6 students had neutral levels of subject *Anxiety* towards Science compared to their other subjects. However, as the students' ages increase across the lower secondary cohorts (Years 7 to 9), students report increasing levels of *Anxiety* compared to their other subjects. This correlates closely with students' perceptions of subject *Difficulty* and their reported *Self-efficacy*. The Year 10 cohort also sees a change in student perceptions in relation to *Difficulty* compared to younger cohorts. This coincides with the offering of the first elective Science course and with the widening of self-reports of *Anxiety* and suggests that offering multiple levels of a Science course can have a mitigating effect on student *Anxiety* towards Science.

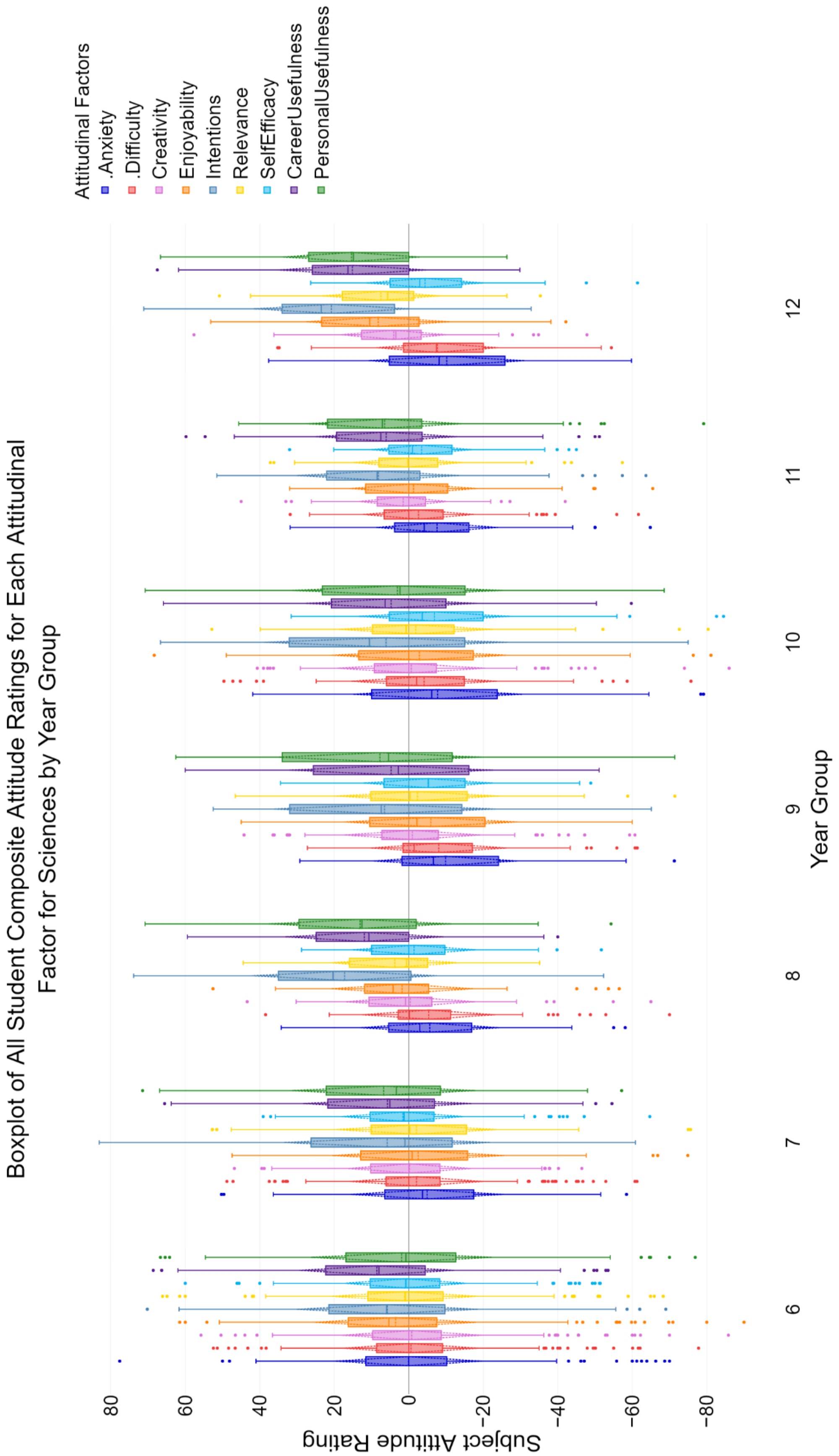

Figure 14. Subject Attitude Profile for Science subjects at Corroboree Frog College grouped by year group

Visit https://schoolattitudes.unisa.edu.au/reports/NCSEHE to view this graph as an interactive.

Considering students' *Intentions* towards further study in Science only, as per the yellow bars in Figure 15, it can be seen that students' ratings became more progressively more positive across the Year 6 to Year 8 cohorts. However, the Year 9 and 10 cohorts in comparison, show that while the upper ratings are fairly comparable with the younger students, the lower ratings became noticeably more negative. This lower tail vanishes by the Year 11 and 12 cohorts when Science is an entirely elective area indicating that those students with negative attitude ratings chose not to continue studying Science. This is indicative of students beginning to show a preference for Science based further study from Year 9 onwards—and conversely, those who have no intention of continuing study in Science were able to indicate this from around 14 or 15 years of age.

Interestingly a similar pattern of attitude broadening was seen in students' ratings of *Enjoyability*, *Career Usefulness* for a career in the sciences and *Personal Usefulness* for a student's personal career (Figure 15). While not implying a causal relationship between these three attitudes and students' *Intentions* for further study in Science, there is some evidence here that outreach and awareness programs aimed at increasing enjoyment of school science, while emphasising the usefulness of the science learned in school both for careers in science and for other careers more broadly, should be targeted at students in late Year 8 and early Year 9 of school (i.e., at around 14 years of age).

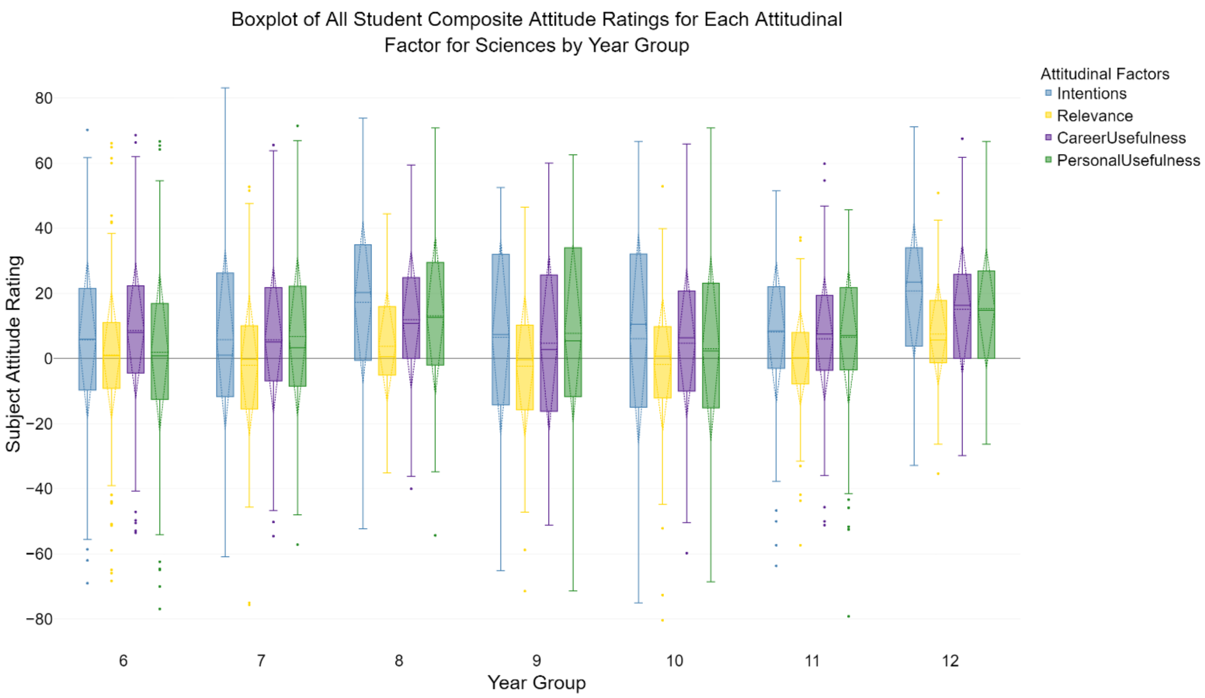

Figure 15. Subject Attitude Profile for selected attitudes for Science subjects at Corroboree Frog College grouped by year group

Figure 16 shows students' attitudes towards science at Corroboree Frog College by gender. Visual inspection of this graph shows that there are very minimal differences between male and female students' attitudes. However, *Anxiety*, *Difficulty*, *Enjoyability* and *Career Usefulness* are worthy of further examination.

Female students' ratings of *Anxiety* (M = -7.0, SD = 20.0) and *Difficulty* (M = -4.6, SD = 18.1) towards Science compared to their other subjects were visibly slightly lower than male students' ratings (M_{Anx} = -3.1, SD_{Anx} = 20.3; M_{Dif} = -2.0, SD_{Dif} = 17.5) but these differences were not statistically significant.

Female students also reported that they found school Science slightly less *Enjoyable* (M = -1.5, SD = 20.8) compared to their other subjects than male students (M = 2.8, SD = 22.6). A two-tailed t-test showed that this difference was statistically significant, $t(1444) = 3.79$, $p = .0002$.

The most visible difference between the male and female students in Figure 16 is with regards to the *Career Usefulness* of school Science for careers in science. Both male and female students reported that school Science was more useful than their other subjects for careers in those subject areas. Male students reported significantly higher ratings for the *Career Usefulness* of Science (M = 10.7, SD =22.5) than female students (M = 5.2, SD =21.4), $t(1444) = 4.76$, $p < .0001$. This suggests that although both male and female students were able to identify that the content taught in Science is more applicable to subject specific careers than the content taught in other subjects, male students were more able to readily relate the content to scientific careers than was the case among female students. However, it is important to note that this does not necessarily imply that male students more readily visualise themselves in scientific careers than their female peers; there was no statistically significant difference between male and female students' rating of the *Personal Usefulness* of school science for their own careers.

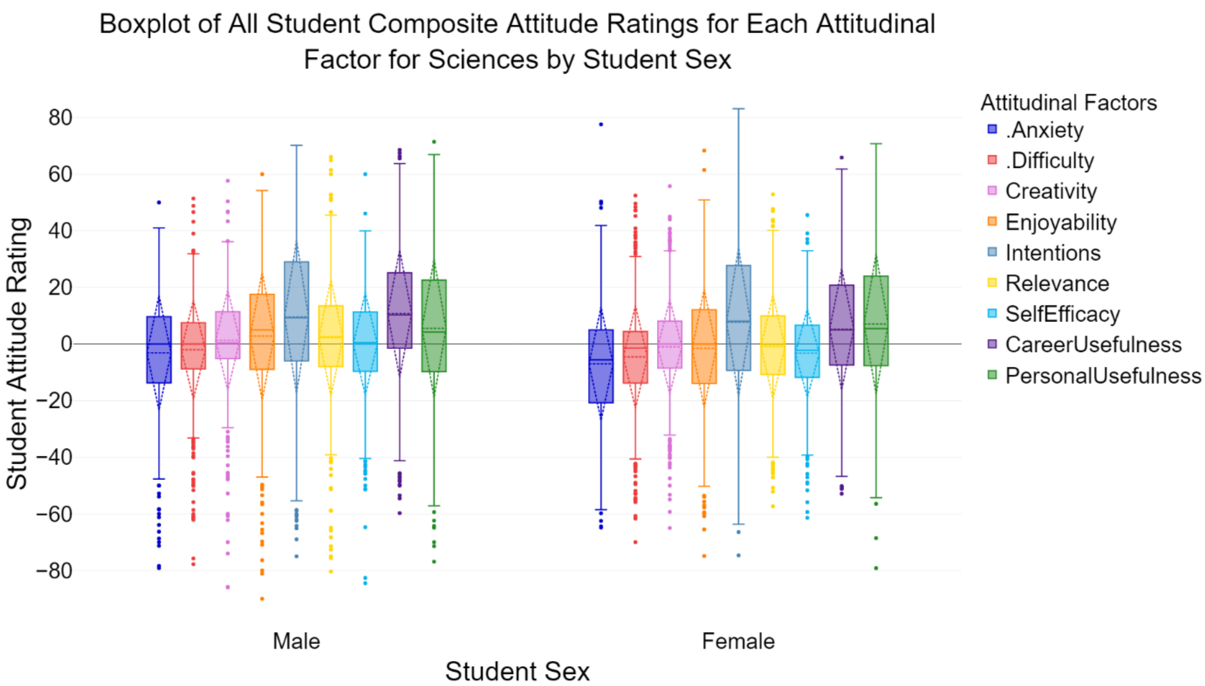

Figure 16. Subject Attitude Profile for Science subjects at Corroboree Frog College grouped by student sex
Visit https://schoolattitudes.unisa.edu.au/reports/NCSEHE to view this graph as an interactive.

Student attitudes towards mathematics

At Corroboree Frog College all students study the same Mathematics course in Years 6 to 8 for 300 (Year 6 and 7) or 250 (Year 8) minutes per week. In Years 9 and 10 students are placed into classes based on ability and study Mathematics at one of three levels for 250 minutes per week: Essential Mathematics, Mathematics Core or Mathematics Extension. Year 10 students intending to study Specialist Mathematics (see below) are able to complete the Year 11 Mathematics course in Year 10.

In Years 11 and 12, the study of some level of mathematics is required for the award of the South Australian Certificate of Education, and a number of pathways are available. Each course is allocated 250 minutes of teaching time per week, with the following combinations possible:

- Year 11 Mathematics and Year 12 Mathematical Methods—a calculus and statistics based course, or Mathematical Methods plus Specialist Mathematics—a course designed for further study in mathematical sciences and engineering.
- Year 11 and 12 General Mathematics—a course designed to give students a non-specialised background in mathematics.
- Year 11 and 12 Essential Mathematics—a course designed to give students mathematical skill in solving everyday numeracy problems.

The many possible study pathways in Mathematics at Corroboree Frog College are shown in Figure 17.

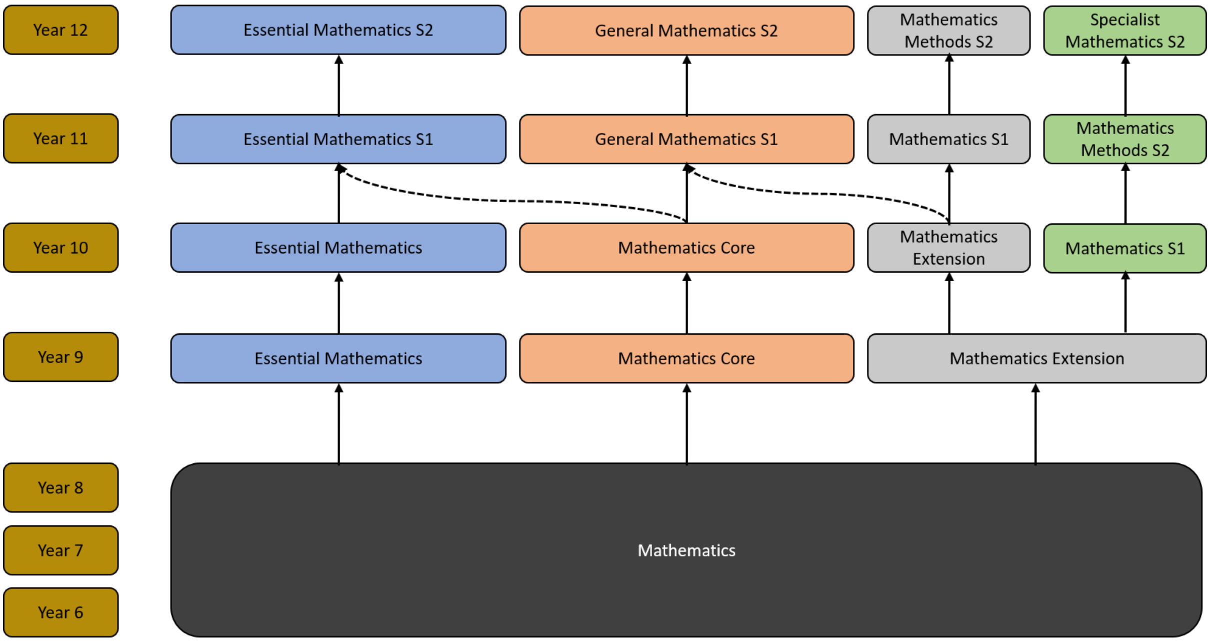

Figure 17. Mathematics study pathways at Corroboree Frog College

Considering the subject attitude profile (Figure 18) for all students towards Mathematics, it can be seen that students reported slightly higher levels of *Anxiety* about Mathematics than their other school subjects (*M* = -6.6, *SD* = 23.5) and also found it slightly more *Difficult* (*M* = -2.5, *SD* = 21.2). Students held positive *Intentions* towards further study in Mathematics (*M* = 6.8, *SD* = 28.4) in comparison to their other subjects and reported that the content they studied in Mathematics held more *Personal Usefulness* for their own career (*M* = 9.7, *SD* = 24.2). However, they also reported that the content they learned in school Mathematics held less *Career Usefulness* (*M* = -10.2, *SD* = 25.1) for a subject specific career (i.e., a career in mathematical sciences) than their other subjects. This is not surprising given that the majority of students are exposed to study pathways (Figure 17) that focus on the general nature of Mathematics and not its specialist applications.

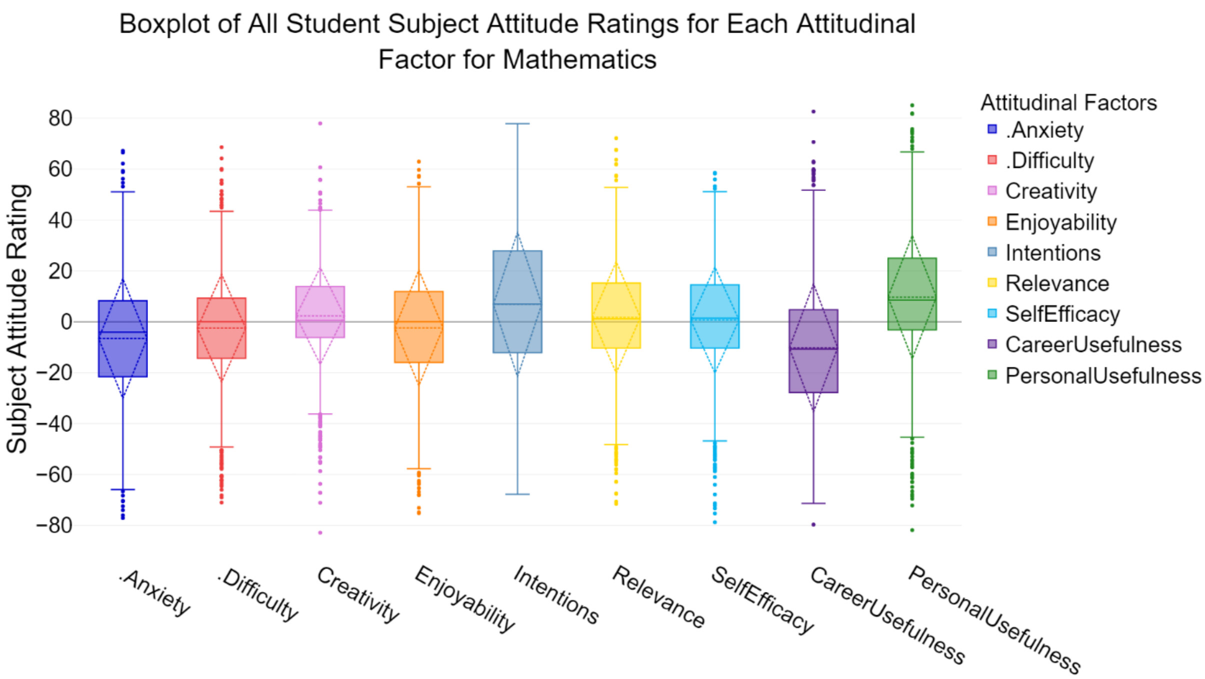

Figure 18. Subject Attitude Profile for Mathematics subjects at Corroboree Frog College for all students
Visit https://schoolattitudes.unisa.edu.au/reports/NCSEHE to view this graph as an interactive.

Figure 19 shows how attitudes towards mathematics change across age cohorts at Corroboree Frog College. Students in Year 6 had very slight negative levels of *Anxiety* (*M* = -1.7, *SD* = 25.8) towards Mathematics. However, *Anxiety* levels increase between cohorts even though the Mathematics curriculum becomes more stratified. After the first level of stratification in Year 9, students' ratings for *Anxiety* in Mathematics were 8.7 points (*SD* = 19.4) more anxious than for their other subjects and after the second major level of stratification in Year 11 they reported as being 11.5 points (*SD* = 22.1) more anxious.

Interestingly, student reports of subject *Difficulty* did not follow the same pattern as *Anxiety*. The Year 6 cohort had essentially neutral attitudes towards the difficulty of mathematics (M = 0.7, SD = 22.3), while the Year 8 cohort reported Mathematics as being slightly more *Difficult* than their other subjects (*M* = -3.1, *SD* =21.2). The Year 9 (M = -4.8, SD = 17.6) and Year 10 (M = -0.9, SD = 19.5) cohorts reported a narrower range of *Difficulty*, indicating that the presence of various pathways in Mathematics from Year 9 onwards may have somewhat helped to address students' perceptions of *Difficulty*; however, these multiple pathways did not address students' subject Anxiety towards Mathematics.

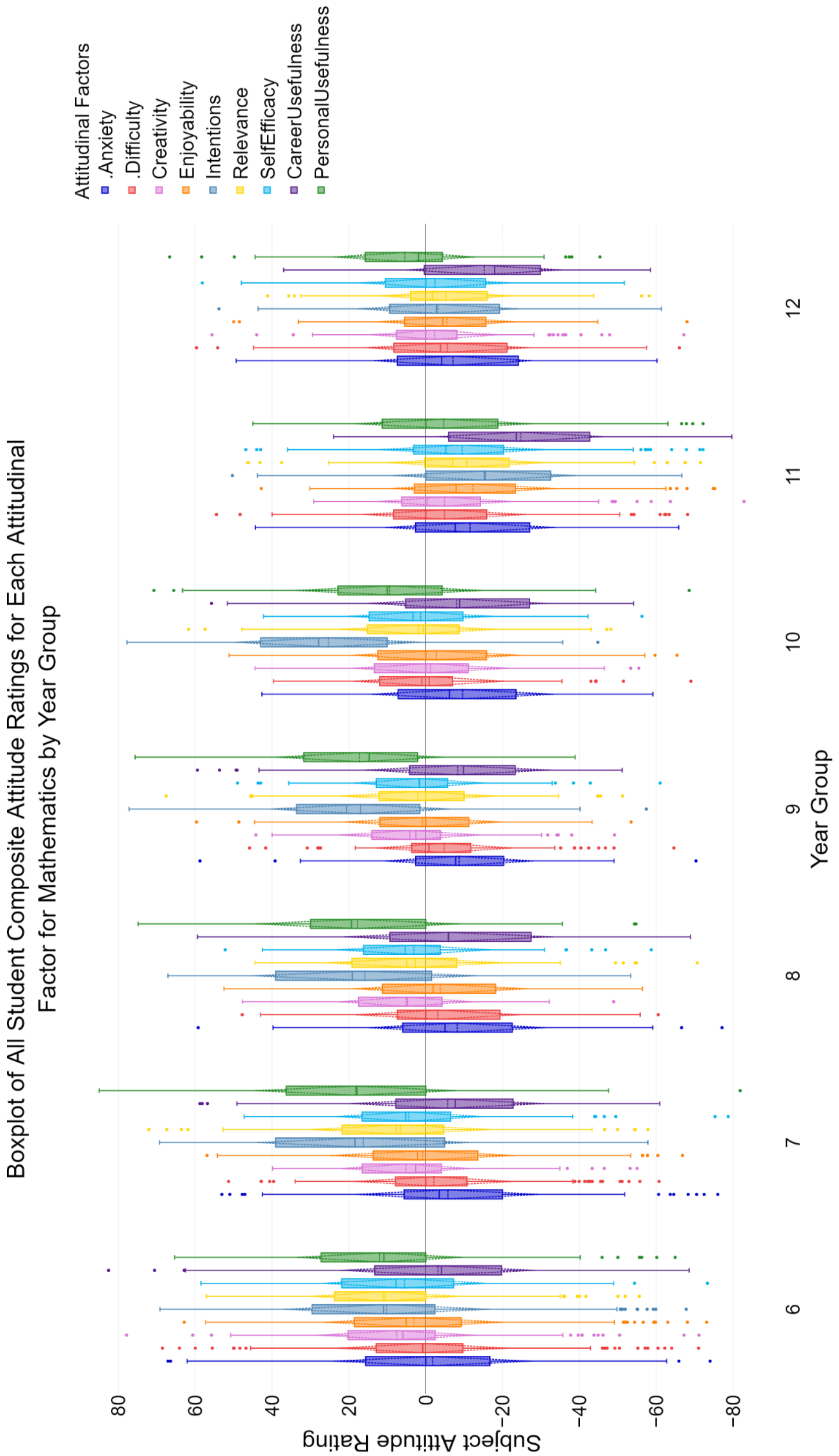

Figure 19. Subject Attitude Profile for Mathematics subjects at Corroboree Frog College grouped by year group

Visit https://schoolattitudes.unisa.edu.au/reports/NCSEHE to view this graph as an interactive.

Also visible in Figure 19 is a declining trend in creativity, enjoyability, subject relevance and self-efficacy in Mathematics between the cohorts as the students become older. While these ratings are generally slightly positive compared to the students' other subject areas, they decrease towards neutral by the Year 10 cohort. This trend could suggest that as students progress through school, they found the content of the Mathematics curriculum to be less immediately relevant to their day-to-day lives and less enjoyable to learn. There is also an impact on their belief in their own mathematical abilities and this may be related to their reported ratings of *Creativity* and *Anxiety* in Mathematics.

Interestingly, students reported increasingly positive *Intentions* towards further study in Mathematics across the Year 6 to Year 10 cohorts. Students also report positive ratings of *Personal Usefulness* of school Mathematics for their own careers. However, students are less positive about the *Career Usefulness* of school Mathematics for careers requiring specialised uses of mathematics.

Taking all these trends together seems to suggest that students have heard the popular message that Mathematics is important for many future careers and that they *should* therefore study the subject at school. Yet, at the same time, the data indicate that older students found the subject increasingly less interesting, less relevant, and an increasing challenge to persevere with.

Figure 20 shows that female students held more negative attitudes towards all aspects of Mathematics than male students at Corroboree Frog College, with a two-tailed t-test showing these effects are all statistically significant at the one per cent level. Of particular interest were student ratings of *Career Usefulness* (M_{male} = -4.5, SD = 25.1, M_{female} = -15.7, SD = 23.9, $t(1444)$ = 8.68, $p < .0001$), *Intentions* (M_{male} = 11.1, SD = 26.5, M_{female} = 2.7, SD = 29.5, $t(1444)$ = 5.70, $p < .0001$), and Mathematics *Anxiety* (M_{male} = -2.1, SD = 22.8, M_{female} = -10.9, SD = 23.4, $t(1444)$ = 7.24, $p < .0001$). These differences in particular support the commonly held idea that female students struggle to visualise themselves in mathematics focussed careers.

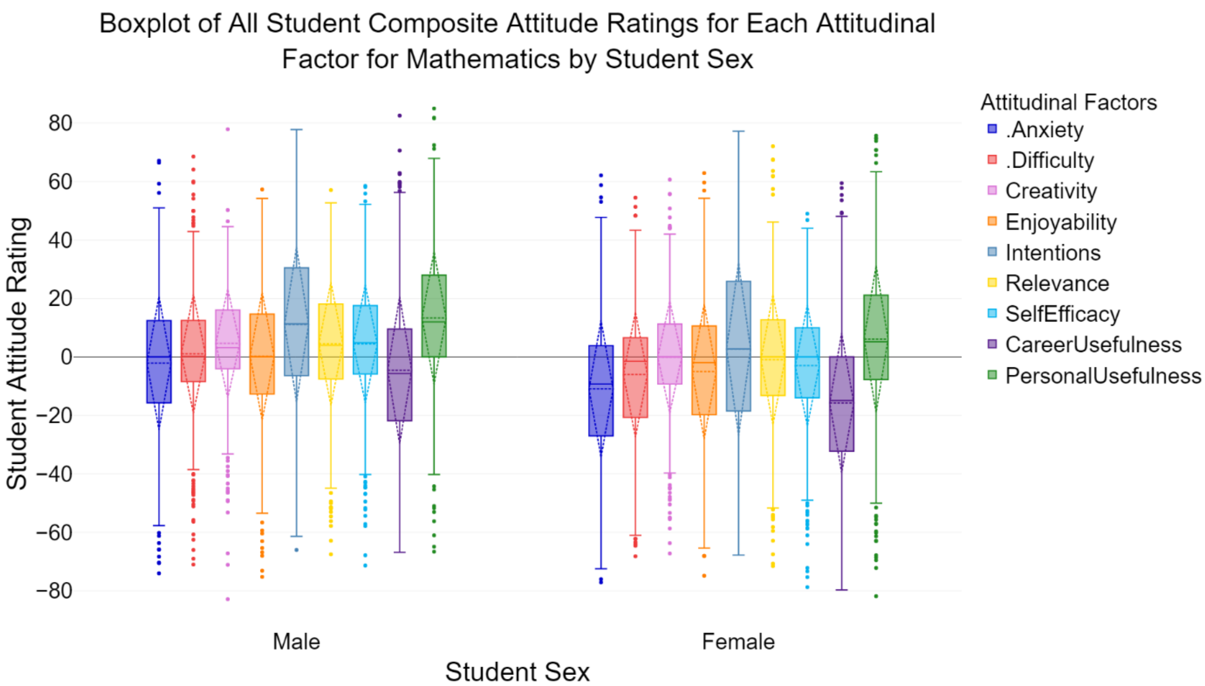

Figure 20. Subject Attitude Profile for Mathematics subjects at Corroboree Frog College grouped by student sex
Visit https://schoolattitudes.unisa.edu.au/reports/NCSEHE to view this graph as an interactive

Discussion and conclusions

This case study has outlined how students' attitudes towards Science and Mathematics as well as towards school more generally can be successfully measured and described using composite and subject attitude profiles. In undertaking this we have established a set of baseline norms against which future measurements can be compared.

We found that students across all year groups at Corroboree Frog College reported on average slightly positive attitudes towards all their school subjects (Figure 8). CARs for *Intentions* and *Career Usefulness* were more neutral in general than other attitudes. We also found that students' *Intentions* towards further study in specific subject areas are strongly related to subject enjoyability for the late primary and early secondary cohorts, but this relationship is less strong in the older cohorts. These patterns may indicate that a substantial number of the students at Corroboree Frog College are forming solid ideas about their own future careers and potentially assessing each subject's usefulness from this frame of reference using a basic cost-benefit analysis. This idea of the formation of an understanding of personal direction is further supported by the narrowing of the range of reported attitudes following each opportunity to select elective subjects. It seems students may be choosing subjects that reinforce their own future goals and, in turn, this sees their CARs in relation to school become more positive. It is therefore reasonable to form two recommendations for outreach programs for schools. Firstly, that programs that aim to develop positive attitudes towards school subjects should attempt to demonstrate the usefulness of subject content knowledge across a wide range of potential careers and not focus too narrowly on one or two specific career pathways. Secondly, that programs that aim to develop awareness of specific career pathways should be designed so as to appeal towards students in the early years of secondary school before their personal career directions begin to crystalise.

In establishing this baseline for CAP, we are able to show that there are minimal differences between the attitudes of male and female students at Corroboree Frog College. Female students reported slightly elevated levels of subject *Anxiety* compared to their male peers, something which may have to be addressed at the whole-of- school level. Male students also reported slightly lower CARs for *Career Usefulness* than female students indicating that they may have a little more difficulty in aligning the content of the curriculum to a specific career. However, the difference reported is not sufficient to suggest that a specific intervention is warranted.

Examination of the Science and Mathematics KLAs at Corroboree Frog College showed that students generally reported that these subjects were more *Difficult* than others and that they felt slightly more subject *Anxiety* about them. Even so, students clearly recognised the importance of these areas, holding relatively positive intentions towards further study in them. Similarly, while students recognised that the content of the Mathematics and Science curricula had the potential to have *Personal Usefulness* for their own career, they were not as positive about the *Career Usefulness* of school Mathematics for a career in the mathematical sciences.

Analysis of the SAP for Science (Figure 14) showed that students' reported *Intentions* for further study in Science increased across the Year 6 to Year 8 cohorts. While the upper ratings of older students remained comparable with the younger cohorts, the lowest ratings became more negative for the Year 9 and 10 cohorts. As noted previously, this lower tail vanishes by the Year 11 and 12 cohorts. This is indicative of students forming an opinion about the potential utility of Science for their personal development at around 14 to 15-years-old. A similar pattern of attitude broadening was seen in Year 6 to year 10 students' ratings of *Enjoyability*, *Career Usefulness* and *Personal Usefulness*. Therefore, it would seem reasonable to suggest that outreach activities with the aim of increasing participation in Science might be most successful if they are implemented for students around 13 to 15-years-old and addressed both *Usefulness* and *Enjoyability* in their design.

The analysis of the Mathematics data reveals a different pattern to Science. Figure 19 showed that subject *Anxiety* steadily increased between cohorts as the students became older while *Difficulty* followed a different pattern. This suggests that the level of stratification in the Mathematics curriculum (Figure 17) may have somewhat addressed the accessibility of the content for students but the availability of multiple pathways has done little to address subject *Anxiety*. Figure 19 also showed steady declining trends in *Creativity*, *Enjoyability*, subject *Relevance* and *Self-efficacy* across the Year 6 to Year 10 cohorts. While these ratings remain positive compared to the students' other subjects, the declining pattern is of concern. Looking at all these patterns together seems to suggest that students have heard the popular message that Mathematics is important for many future careers and that they *should* continue to study the subject at school. Yet, the data seem to suggest that as students become older they find the subject increasingly less interesting, less relevant, and an increasing challenge to persevere with. It would therefore be recommended that programs that in particular target older students' participation in Mathematics should continue to focus on communicating the relevance and interesting applications of the subject to the students.

The Science SAP shows a noticeable turning point in attitudes around Year 8 and 9. The lack of a noticeable turning point in the attitude patterns seen for Mathematics seems to suggest that the formation of these attitudes occurs early on in schooling and likely prior to Year 6. It is therefore important that further research is carried out to examine students' attitudes to Mathematics in the earlier years of schooling. At the other end of the school journey, even with the narrative of essentiality told by schools about Mathematics and the flexibility of the various pathways available for its study, there is a drop in all reported attitudes towards Mathematics for the Years 11 and 12 cohorts at Corroboree Frog College. There could be many factors responsible for these patterns of attitudes including the change of campus and teaching staff for students between the Year 10 and Year 11 cohorts, the additional stresses associated with the SACE, or the semi-compulsory nature of Mathematics. However, a similar drop is not seen in the Science data (Figure 14) or the general school data (Figure 9). It is therefore reasonable to suggest that the cause of this decline in attitudes rests with the fundamental nature of the Mathematics courses and their implementation and this needs further investigation.

Case study two - The impact of COVID-19

The COVID-19 pandemic has had a significant impact upon society and education globally. Aside from the wider public health and economic impacts, it has seen educational providers around the world forced to rapidly pivot to online learning during 2020 (Basilaia & Kvavadze, 2020; OECD, 2020). Although Australian higher education already operates extensively in the online space, the transition to online-mediated distance learning in schooling has been as extraordinary as it has been unexpected, with Hong Kong during the SARS outbreak of 2003 offering perhaps the only significant precedent (Fox, 2004).

This case study presents the experiences of the early days of the COVID-19 pandemic as self-reported by the students of two schools in Australia. The data presented here were collected using the SAS and are a snapshot taken during the initial response to the pandemic. The data come from students in Years 10 to 12 (15 to 18-years-old) who attended schools where online learning was present but did not form a significant part of the learning design prior to the COVID-19 crisis.

This case study has been further explored in an article titled "Secondary Education in COVID Lockdown: More Anxious and Less Creative-Maybe Not?" in the journal *Frontiers in Psychology* (Patston et al., 2021).

At the start of the academic year in January, students were expecting a school year dominated by traditional face-to-face learning, and most would have been looking ahead to prospects within a relatively strong labour market or entry to university. Often, they may have been considering a "gap year" between school and university with a year spent traveling and possibly working abroad. By March however, these students were facing a very different reality. Australia's international borders, and ultimately its state borders, were closing to all but essential travel. Thoughts of travel and study overseas or even interstate were at best, uncertain. With unemployment projected to tip 13 per cent and youth unemployment climbing much higher, of the option of working from home was no more definite. To add to this picture the Australian university sector, heavily reliant on international students, was in chaos having shed thousands of academic jobs. On seemingly every front, the "certainties" of their future had been upended to a degree perhaps only surpassed during the World Wars.

Both Corroboree Frog College and Green Tree Frog School students provided data for this case study. The pandemic experience at these two schools was quite different. Green Tree Frog School is located in the Australian state which had the largest outbreak of the virus. In late March 2020, towards the end of the first term of the school year, it initially closed face-to-face teaching for nine weeks. Upon returning to campus, its boarding houses necessitated the implementation of quite extreme social distancing and hygiene protocols before a new outbreak of the virus ended face-to-face teaching once again. Corroboree Frog College, on the other hand, is located in a state where the virus was quickly contained during the first wave, and which experienced no further major outbreaks. This meant that school life at Corroboree Frog College was able to return to something very close to normal after an extra week of school holidays in April and only a short period of online-mediated distance learning. Corroboree Frog College students have still had to deal with the social, emotional, and economic impacts of COVID-19, but in terms of the day-to-day activities, the changes to teaching and learning have been relatively moderate.

School context and participants

In an attempt to maintain normalcy for its students, Green Tree Frog School took a uniform approach to online learning. Within that structure, students were encouraged by teachers to develop individual methods of information transfer, information consolidation, and information retrieval. Students were also encouraged to maintain their handwriting skills and upload photos of their physical work to the digital platform. This standardised learning format had been in place for five weeks when the SAS was conducted.

Corroboree Frog College adopted a more flexible approach to learning that encouraged teachers to individually adopt various technologies and strategies, and to take the opportunity of the pandemic to explore novel approaches to online learning. The intent and nature of online learning varied across year levels and different parts of the multi-campus school, according to the various needs of students. Students typically engaged in a weekly web-conference for each subject which provided support for online learning activities and opportunities for collaboration and connection to peers and teachers.

Green Tree Frog School has explicitly incorporated the ideas and principles of creative education into its curriculum for around three years. Corroboree Frog College has recently shifted its strategic intent to improve student attainment of twenty-first century capabilities and has started to invest in resources and professional development for teachers to foster student creativity.

All Year 10, 11 and 12 students (15 to 18-year-olds) at both schools were invited to contribute data to the SAS instrument via a personalized email link in the penultimate week of Term 2 2020. Students were allocated time during a nominated class to complete the SAS instrument using their own computer or other device (e.g., iPad). The profile of the two school samples is shown in Table 4. These represent a response rate of 67 per cent at Green Tree Frog School and 51 per cent at Corroboree Frog College.

Table 4. Student sample profile for Corroboree Frog College and Green Tree Frog School.

Student Sex	Corroboree Frog College				Green Tree Frog School				Grand Total
	Year 10	Year 11	Year 12	Total	Year 10	Year 11	Year 12	Total	
Male	13	75	80	168	53	55	76	184	352
Female	29	101	89	219	82	75	106	263	482
Total	42	176	169	387	135	130	182	447	834
Grand Total	177	306	351	834	177	306	351	834	

Patterns of interest, both within and between schools, were identified and investigated through the use of boxplot comparisons, ANOVA and correlation analysis using various packages available in the R statistical environment (R Core Team, 2018). Quantile-Quantile plots and the Shapiro-Wilk W-statistic were utilized to ensure sufficient normality in the data for the use of parametric analysis. Pearson's product moment coefficient *(r)* was used to analyse the strength of correlations between attitudinal factors in an attitude profile. Tukey's Honest Significance Test, with a 95% confidence interval, was used to determine the extent of the differences in the population means identified by the ANOVA results and eta-squared *(η^2)* was used as a measure of effect size. The relative strength of the different relationships will be interpreted using Cohen's (Cohen, 1988) "rule of thumb" and are shown in Table 5.

Table 5. Magnitudes of effect size based on the general rule of thumb of Cohen (1988)

Statistical Measure	Effect Size Threshold		
	Small	Moderate	Strong
Correlation (Pearson's r)	0.10	0.30	0.50
ANOVA (η^2)	0.01	0.06	0.14
Cohen's d	0.20	0.50	0.80

Australia has a nation-wide curriculum (Australian Curriculum, Assessment and Reporting Authority, 2021) that is implemented and assessed on a state-by-state basis. For example, although the general content of the English curriculum is the same in all states, the details regarding its delivery and assessment are not directly comparable. In addition, Australian school leaving credentials do not usually require the study of any mandatory subjects in Years 11 and 12 except for English. Hence, sample sizes for other subjects can readily fall below those needed for reliable generalizations to be made. It is therefore unreasonable to compare students' attitude profiles on a per subject basis. However, courses with similar approaches to learning from both schools can be grouped together into several subject areas—known as Key Learning Areas (KLAs)—for analysis. This approach becomes more useful when only considering Year 11 and 12 students as the various syllabuses for this stage of school are more consistent between States. For the following analyses we considered two KLAs: Mathematics—comprising both elementary, intermediate and advanced mathematics courses—and Sciences—comprising courses in physics, chemistry and biology.

While there are some potentially interesting differences between the attitudinal profiles for the two schools in this study at the individual subject level that require more detailed analysis, we constrained our results, and the discussion in this report, to the school-wide composite attitude ratings, the grouping factors of student year group and student sex, and the combined KLA subject attitude ratings. The nature of COVID-19 is also likely to have had a dampening effect on students' long-term attitudes and intentions towards their subjects. Hence, we will also restrict our analysis to just six of the attitudinal constructs of the SAS: *Difficulty*, subject *Anxiety*, *Self-efficacy*, *Enjoyability*, perceived subject *Relevance*, and *Creativity*.

School composite attitude ratings

Figure 21 shows the composite attitude profile of the students at Corroboree Frog College (left hand boxes) and Green Tree Frog School (right hand boxes) towards all academic subjects. For each attitudinal factor, the box represents the interquartile range, the solid horizontal line indicates the median and the whiskers indicate 1.5 times the interquartile range. The diamond is centred on the mean and extends one standard deviation in either direction. Circular markers indicate potential outliers in the data. As can be seen, the mean reported attitudes were slightly positive for all attitudinal constructs, indicative of a student cohort who are uncertain about the COVID-19 crisis but who nonetheless have a generally positive outlook on school.

The figure suggests that the attitudinal positions held by students at the two schools were in fact very similar, even though the experiences of COVID-19 for the students at these schools were markedly different. This similarity is confirmed by a two-way ANOVA which shows that the effect sizes of any statistically significant differences between the schools were small. Ratings for *Self-efficacy* by students at Corroboree Frog College were 2.96 points higher ($F(1,820) = 9.61$, $p = .002$, $\eta^2 = 0.012$) than students' ratings at Green Tree Frog School. Ratings for *Creativity* at Corroboree Frog College were 4.0 points higher ($F(1,809) = 16.24$, $p < .001$, $\eta^2 = 0.020$) than at Green Tree Frog School. When the gender variable was included, a number of apparently statistically significant relationships were revealed. However, none of these results reach the threshold value of eta-squared for a small effect size, as outlined in Table 5, and so they were not treated as being statistically meaningful.

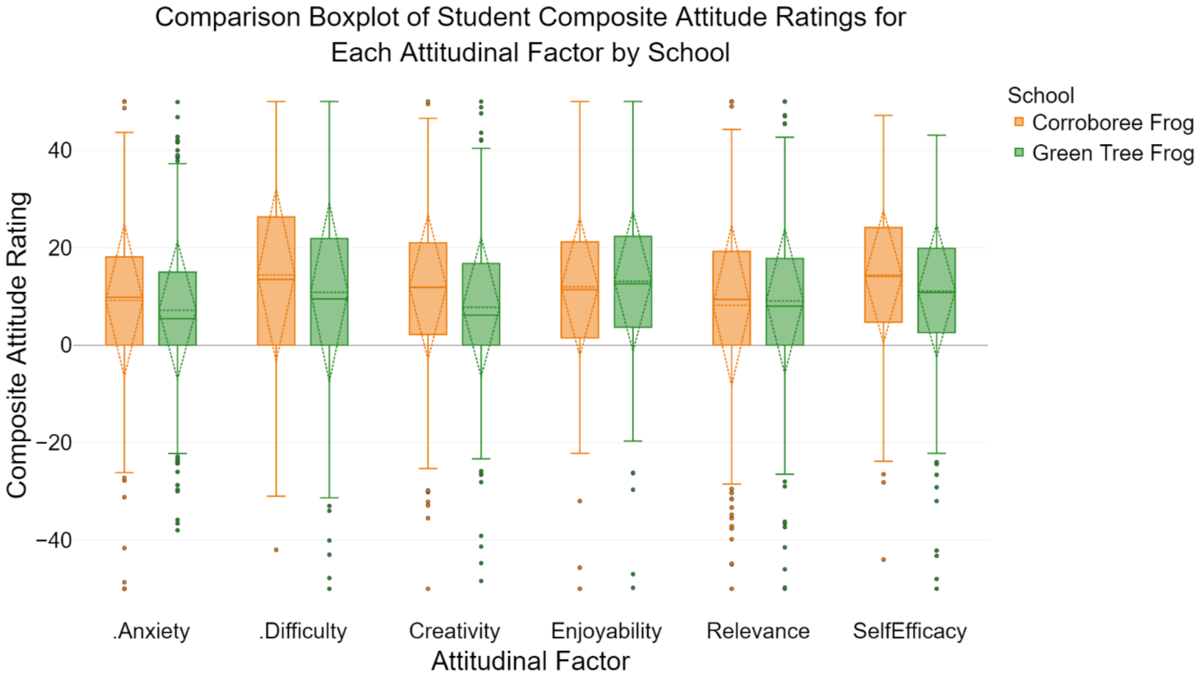

Figure 21. Composite Attitude Profile for all Year 10-12 students at Corroboree Frog College (left hand bars) and Green Tree Frog School (right hand bars)
Visit https://schoolattitudes.unisa.edu.au/reports/NCSEHE to view this graph as an interactive

A pairwise correlation analysis, with a Bonferroni adjustment, was performed in relation to the attitudinal factors, for each of the schools independently. These are shown in Table 6 with the correlations for Corroboree Frog College (r_{CFC}) below the diagonal and those for Green Tree Frog School (r_{GTFS}) above. All correlations were found to be highly statistically significant ($p < .001$). There were no meaningful correlations found between a student's gender or year group and their CAR for any attitudinal factor for students at either school.

As can be seen in Table 6, *Creativity* correlates positively and favourably with *Enjoyability Relevance*, and *Self-efficacy* while correlating negatively with perceived *Difficulty*, and subject *Anxiety*. This evidences the inter-dependent relationship of these factors—as students' subject creativity ratings increase, their subject Anxiety ratings decrease, they find the subject easier and their ratings of self-efficacy, enjoyability and relevance also increase. It can also be seen that enjoyability, relevance and self-efficacy are strongly correlated with each other suggesting that these three attitudes may be related to common influences.

Table 6. Correlation coefficients between Attitudinal Factors for all students at Corroboree Frog College (below the diagonal) and Green Tree Frog School (above the diagonal)

	Anxiety	Creativity	Difficulty	Enjoyability	Relevance	Self-Efficacy
Anxiety		-0.49	**0.48**	-0.53†	-0.44	-0.51†
Creativity	-0.43		-0.28	**0.54†**	**0.49**	**0.44**
Difficulty	**0.49**	-0.38		-0.39	-0.22	-0.44
Enjoyability	-0.39	**0.47**	-0.38		**0.49**	**0.52†**
Relevance	-0.36	**0.44**	-0.28	**0.58†**		**0.39**
Self-Efficacy	-0.47	**0.44**	-0.41	**0.51†**	**0.34**	

Corroboree Frog School (below the diagonal); ***Green Tree Frog School*** (above the diagonal)

Note: Bold text has been used to indicate a moderate correlation (r>0.30). Bold text and a dagger symbol have been used to indicate a strong correlation (r>0.50).

Science subject attitude ratings

Figure 22 shows the subject attitude profile for Year 11 and 12 students for courses in the Sciences KLA. In both schools, all students study an integrated or general science course until the end of Year 10. In Years 11 and 12, students are free to choose among courses from the Sciences KLA, including not selecting a course. Options can be domain-specific, such as Biology, Chemistry or Physics, or generic, such as Scientific Studies. The data presented in Figure 22 therefore represents the SARs of students that chose to include *at least* one science course in their curriculum, and the number of data points exceeds the number of students.

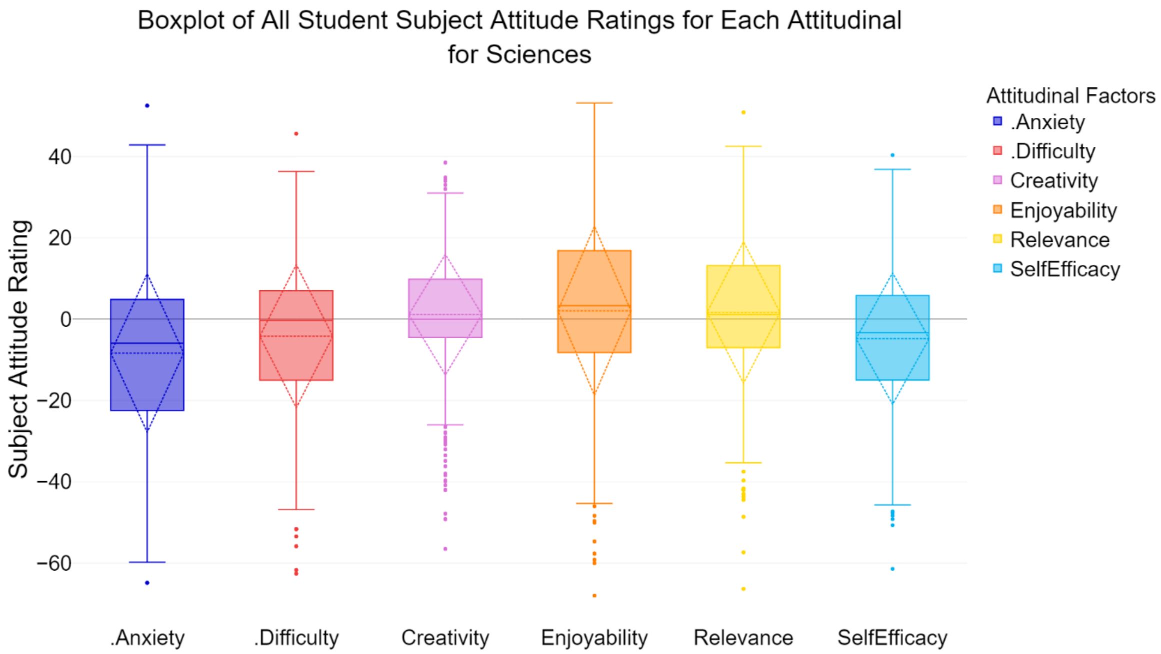

Figure 22. Subject Attitude Profile for Year 11-12 students studying at least one course from the Sciences KLA at both Corroboree Frog College and Green Tree Frog School
Visit https://schoolattitudes.unisa.edu.au/reports/NCSEHE to view this graph as an interactive

Figure 22 shows the attitudes of students towards the Science KLA compared to those students' attitudes towards their other subjects. For example, the visibly negative SAR for *Anxiety* indicates that these students were more anxious about their Science courses than they were about their other courses. A two-tailed one-sample t-test was performed to determine if the means of the SARs were statistically significantly different to the CARs of the students taking at least one course in the Sciences KLA. SARs for subject *Anxiety* (M = -8.86, SD = 18.91, $t(1275)$ = 16.72, $p < .001$, d = 0.47), perceived *Difficulty* (M = -4.60, SD = 17.35, $t(1272)$ = 9.46, $p < .001$, d = 0.27), and *Self-efficacy* (M = -4.85, SD = 16.17, $t(1266)$ = 10.67, $p < .001$, d = 0.30) were all statistically less than the students' CARs and had small effect sizes. SARs for *Creativity* (M = 1.19, SD = 14.33, $t(1270)$ = 2.95, p = .003, d = 0.08), *Enjoyability* (M = 2.03, SD = 19.98, $t(1269)$ = 3.62, $p < .001$, d = 0.10), and *Relevance* (M = 1.48, SD = 17.14, $t(1270)$ = 3.09, p = .002, d = 0.09) were all more positive than the CARs for these students and these were all statistically significant but of negligible effect size.

Analysis of the correlations between the different attitudinal factors for the Sciences KLA showed that *Enjoyability* was found to be strongly correlated with both *Relevance* and *Self-efficacy* which are in turn moderately correlated with each other. C*reativity* was borderline strongly correlated with this triplet of attitudinal factors. The full correlation matrix of attitudinal factors is given as Table 7.

Table 7. Correlation coefficients between Attitudinal Factors for all Year 11 and 12 students at both schools studying a course from the Sciences KLA

	Anxiety	Creativity	Difficulty	Enjoyability	Relevance	Self-Efficacy
Anxiety						
Creativity	*-0.39*					
Difficulty	***0.54†***	*-0.35*				
Enjoyability	*-0.38*	***0.48***	*-0.34*			
Relevance	*-0.31*	***0.42***	*-0.33*	***0.52†***		
Self-Efficacy	*-0.64†*	***0.48***	*-0.53†*	***0.53†***	***0.39***	

Note: Bold text has been used to indicate a moderate correlation (r>0.30). Bold text and a dagger symbol have been used to indicate a strong correlation (r>0.50).

Mathematics subject attitude ratings

Figure 22 shows the subject attitude profile for Year 11 and 12 students for courses in the Mathematics KLA. Australian schools offer mathematics courses at two or three levels of complexity from Year 9 onwards and the study of mathematics is compulsory until the completion of Year 10 (see Figure 17 for the pathways available at Corroboree Frog College). In Year 11 and 12, students may elect to study mathematics at one of three levels—elementary level e.g., financial mathematics and algebra; intermediate level e.g., algebra, geometry and non-calculus mathematics; advanced level e.g., calculus mathematics—or not at all. The data presented in Figure 23 represent the SARs of students who have chosen to include some level of mathematics study in their curriculum.

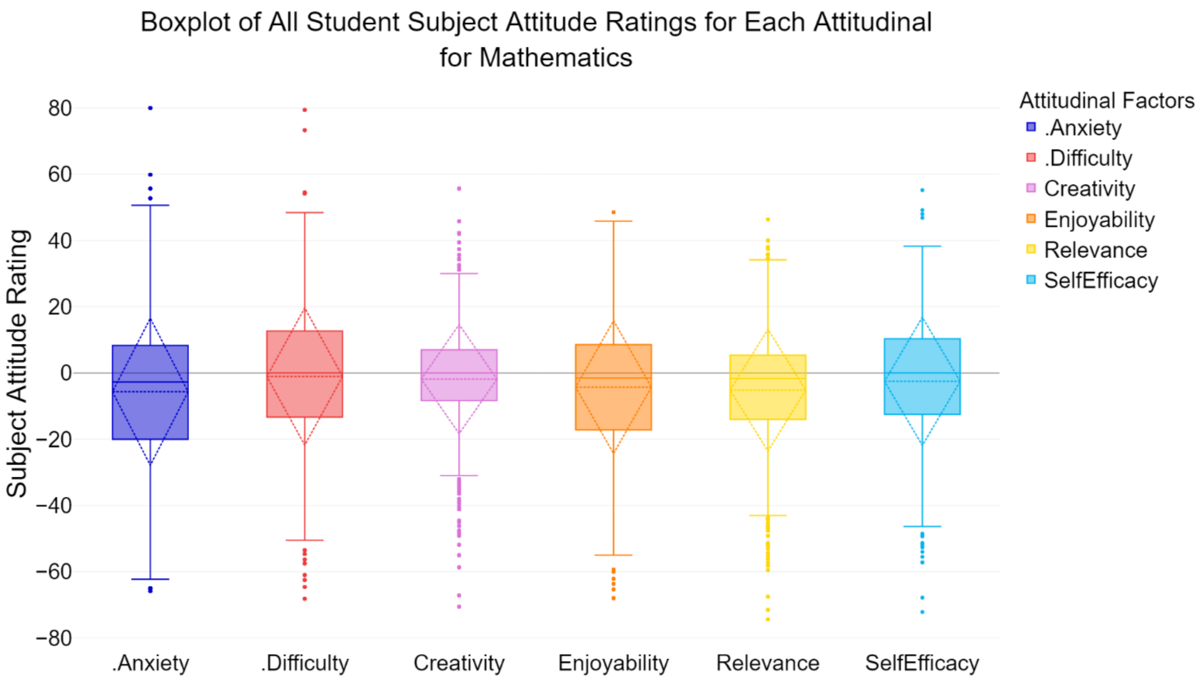

Figure 23. Subject Attitude Profile for Year 11-12 students studying at least one course from the Mathematics KLA at both Corroboree Frog College and Green Tree Frog School
Visit https://schoolattitudes.unisa.edu.au/reports/NCSEHE to view this graph as an interactive

Again, a two-sided one-sample t-test was carried out to determine if the mean SARs for these attitudinal factors were statistically different from the students' CARs. The means of all the SARs were less than these students CARs; however, this difference was not statistically significant for perceived *Difficulty*. Subject *Anxiety* (M = -6.26, SD = 21.94, $t(541)$ = 6.64, p < .001, d = 0.29), *Creativity* (M = -2.24, SD = 16.01, $t(542)$ = 3.26, p = .001, d = 0.14), *Enjoyability* (M = -5.16, SD = 19.86, $t(543)$ = 6.06, p < .001, d = 0.26), *Relevance* (M = -5.87, SD = 17.98, $t(542)$ = 7.60, p < .001, d = 0.33), and *Self-efficacy* (M = -2.99, SD = 19.40, $t(542)$ = 3.59, p < .001, d = 0.15) ratings were all statistically significantly negative compared to their CAR and had small effect sizes.

Analysis of the correlations between the attitudinal factors for the Mathematics KLA showed that the correlations between *Enjoyability*, *Relevance* and *Self-efficacy* were again strong or borderline strong suggesting the interdependence of these three constructs within Mathematics. *Creativity* correlated strongly with *Enjoyability* but only moderately with *Relevance* and *Self-efficacy*. The full correlation matrix is given as Table 8.

Table 8. Correlation coefficients between Attitudinal Factors for all Year 11 and 12 students at both schools studying a course from the Mathematics KLA

	Anxiety	Creativity	Difficulty	Enjoyability	Relevance	Self-Efficacy
Anxiety						
Creativity	-0.42					
Difficulty	**0.68†**	-0.40				
Enjoyability	-0.56†	**0.49**	-0.47			
Relevance	-0.46	**0.36**	-0.41	**0.50†**		
Self-Efficacy	-0.76†	**0.39**	-0.65†	**0.58†**	**0.48**	

Note: Bold text has been used to indicate a moderate correlation (r>0.30). Bold text and a dagger symbol have been used to indicate a strong correlation (r>0.50).

Discussion and conclusions

Figure 21 shows composite attitude profiles that are very similar for students at both Corroboree Frog College and Green Tree Frog School. This indicates that the very different social and educational responses to COVID-19 experienced by students at the two schools appears to have had very little effect on students' attitudes towards their learning. Furthermore, the student composite attitude profiles are generally positive, even in a time of societal crisis, which speaks to the resilience and flexibility of the students in adapting to new modalities of pedagogy. It also suggests that the schools' responses to COVID-19 appear to have mitigated many of the potentially negative effects on student attitudes and students continue to hold generally positive attitudes towards the academic aspects of school as a whole.

As discussed, students' attitudes towards *Creativity* and *Self-efficacy* were slightly more positive at Corroboree Frog College than at Green Tree Frog School. While it might seem reasonable to suggest that the continuing uncertainty surrounding COVID-19, reduced direct and immediate access to teaching staff, and the extended period spent engaged in online learning by students at Green Tree Frog School could be a contributing factor to these differences, it is impossible to say for certain whether or not this is in fact the case. Further research is required in this area to determine the nature of the attitude profiles at the two schools once they return to a semblance of normality.

Kennedy et al. (2018) showed that the attitudinal factors of *Enjoyability*, *Self-efficacy*, and *Relevance* were closely linked for Year 7 students studying Science and Mathematics. As we have shown in Table 6, Table 7 and Table 8, this triplet of attitudes continues to be moderately to strongly correlated with each other in general and in both the Science and Mathematics KLAs for the Year 11 and 12 students analysed in this study. We have also shown that subject *Anxiety* and *Self-efficacy* are, not unsurprisingly, strongly and negatively correlated with each other across these KLAs. These patterns are interesting as they suggest that there may be feedback mechanisms present between these various attitudinal factors that are similar to each other across KLAs or skill domains. In turn, this may offer opportunities for further research into various academic interventions that could help to shape students' attitudes and assist in developing a more positive view of self-concept for students.

In this study we investigated the construct of *Creativity* using the SAS. In doing so, we carefully worded the item to describe the *action* of learning creatively. We have found that *Creativity* is closely correlated with the triplet of attitudes previously discussed for both KLAs analysed. This is particularly interesting because, while the triplet of attitudes measures value based or perceived attitudinal constructs, our creativity construct is action based. That is, *Creativity* as defined and described in this report is a teachable skill and approach to learning. Therefore, *Creativity* may have some potential to be a mechanism to affect the positive changes in students' other attitudes and may in turn be able to assist in reducing subject *Anxiety* and students' perceptions of relative *Difficulty*.

However, while there are some common patterns Between Science and Mathematics, Figure 27 and Figure 28 also show differences in the nature of the SARs between the KLAs. Students are slightly more *Anxious* about their Mathematics course and find it less *Enjoyable* and *Relevant* than their other subjects. They also find it slightly more *Difficult* than their other courses and report slightly lower *Creativity* and *Self-efficacy* towards it. As Mathematics is an elective KLA—even though it is studied by the majority of students—this seems a little incongruous. Further research is clearly needed in this area.

The differences between the Mathematics KLA and the Science KLA shows that students hold different attitudes towards the different domains of their curriculum, and this suggests that a one size fits all approach to learning does not exist across the different KLAs and that any potential interventions may need to be KLA specific or focused.

Case study three - The impact of an educational program in a technology enhanced learning environment

A key aspect of successful learning in STEM is the ability to think and reason spatially. Spatial reasoning has gained enormous attention within the field of Mathematics Education since the 1970s, coupled with increasing research focus in fields such as the Cognitive Neurosciences, Mathematics, Psychology and Philosophy (Bruce et al., 2016; Lowrie & Jorgensen, 2018). The importance of this research is evident in the way humans as embodied, situated beings (Lakoff & Núñez, 2001) interact between spatial models of objects, spatial relations between objects, or exploring the spatial coordinates of places and spaces (Uttal et al., 2013).

This case study outlines changes in students' attitudes towards science and mathematics in response to a week-long program of spatial-learning activities conducted within a technology-enhanced learning environment (TELE). In recent years many schools and school systems in Australia (e.g. South Australia Department for Education, 2020), as in other parts of the world (Community Research and Development Information Service, 2020), have made major capital investments into TELEs, generally in the form of dedicated "STEM" buildings. This move follows a similar investment in so-called 'next generation' learning spaces in many higher education campuses around the world (Leonard et al., 2017; Matthews et al., 2011). At both levels of education these spaces tend to reify a distinctly *constructivist/social constructivist* understanding of learning and to promote the opportunity for student led—and typically collaborative—problem solving.

This case study has been further explored in an article titled "Technology enhanced learning environments and the potential for enhancing spatial reasoning: a mixed methods study" in the journal *Mathematics Education Research Journal (Fowler et al., 2021).*

Despite some now dated reviews (Blackmore et al., 2011; Scottish Funding Council, 2006), research on the impact that these spaces have on students remains nascent. Indeed, there is a strong sense in the literature that the dominant narratives of "twenty-first century change" vastly outweigh empirical evidence as the basis for this investment (see for example Carvalho & Yeoman, 2018). Within the empirical work that does exist, though, there is a strong suggestion that the relationship between the learning space and changes in learning is complex. Waldrip et al. (2014), for example, find that the connection between student performance and a "next generation" learning space seemed to be mediated by impacts on student well-being. Accounting for these complex effects is of increasing interest to educational researchers (Leonard et al., 2017; Woolcott et al., 2016) and has an important influence on the design of the present study.

This case study aims to address the research question, does an intense visit to a TELE result in measurable changes in students' attitudes towards school Science and mathematics?

School context and participants

The participants in this study were Year 7 students from two campuses of Corroboree Frog College (Table 9). At the time of the study, the college had recently opened a central TELE to be used by students from all campuses, known as The Innovation and Creativity School (TICS). The common use of this facility between the different campuses had led to an initial learning design involving what were, in effect, week-long excursions to TICS. That is, students worked on various projects within the TICS building for a week instead of their regular class activities, with classes from the different campuses of the college rotating through the space.

This study also took place in the middle of the early stages of the COVID-19 pandemic and was subsequently suspended for some time due to related school closures. The impact of this disruption is unclear, but for some students in the study, the time at TICS represents the majority of their face-to-face school for some weeks, with the rest of their learning moving to online engagement from their homes.

Table 9. Composition of the sample groups

	Male	Female	Total
Group 1	16	18	34
Group 2	41	32	73
Totals	**57**	**50**	**107**

Two groups of Year 7 students were involved in a week of rotational tasks using technologically mediated pedagogies. The two groups' visits provide two lenses through which to evaluate the effectiveness of a TELE experience. The attitudes of Group 1 were measured following a week-long visit to TICS and represent for this study a comparative baseline for student attitudes after being exposed to the cumulative effects of the learning experience. The attitudes of Group 2 were first measured at the same time as Group 1, i.e., before they had the opportunity to visit TICS. Their attitudes were then measured again immediately following the week-long experience. Measurement and visit times are shown in the timeline in Figure 24.

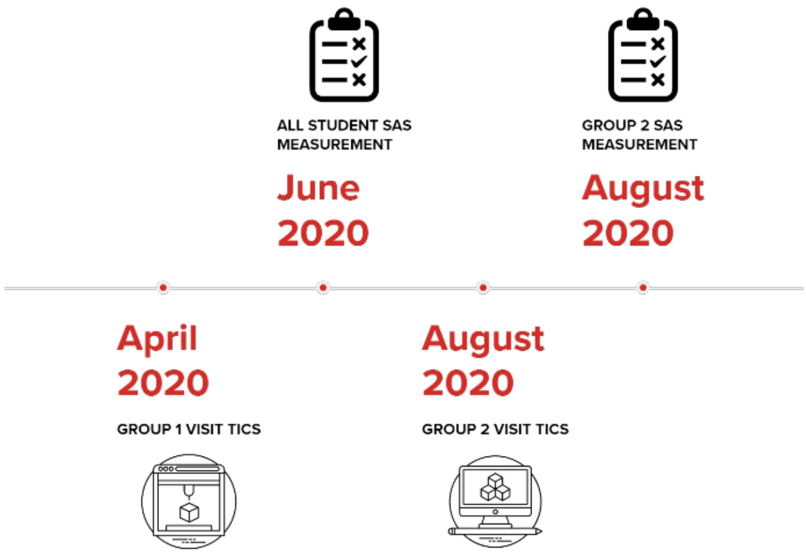

Figure 24. Timeline of visits to TICS and SAS measurement points

The TELE experience

The lessons delivered to students at TICS were developed by teachers at Corroboree Frog College and were delivered by digital technology teachers working in the TICS. Each activity was designed by the College staff to focus on one or more STEM skill areas (Table 10). Students in Group 1 participated in four of the activities over a week, spending around three hours on each activity. Group 2 was a physically larger group of students. The College staff therefore added a fifth activity so as to reduce the numbers of students in each group and ensure that good student to technology ratios could be maintained.

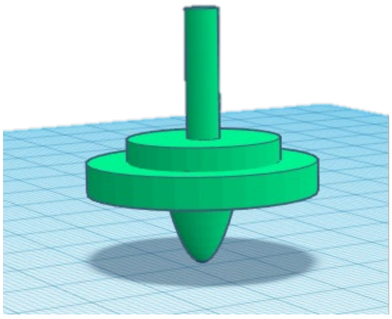

Figure 25. A spinning top design in TinkerCAD

The activities included:

- A 3D modelling activity examined the motion of a spinning top and factors affecting its spinning time. After experimenting with example tops and being introduced to TinkerCAD skills, the students used their analysis of the experiments to design their own tops which were later printed on a 3D printer and tested for effectiveness.
- A robotic engineering lesson introduced students to advanced block coding using “mBots”. These robots are coded to move at various angles and use advanced sensors to measure distances and aspects of tilting. Throughout the day students were challenged by tasks of ever-increasing complexity, that required their knowledge of abstraction, algorithms, simulation, and evaluation.
- A GPS (global position system) in sport session used trackers during an outdoor physical session to provide data for excel analysis relating to concepts such as top speed, speed zones and distance travelled.
- Lessons on webpage design exploring how to create a webpage using the underlying HTML code and teaching the basics of engineering design in a coding context.
- A digital innovation and creativity course using Adobe Spark to develop a persuasive text using storytelling features and the fundamentals of visual design in the digital world.

The tasks identified to have the most potential for engaging in spatial reasoning were the 3D modelling—due to the focus on virtually rotating, splitting and combining 3D objects—and robotic engineering—with its focus on navigation. The webpage design and Adobe Spark courses were designed to focus on digital creativity more than specific STEM knowledge or Spatial reasoning skill development.

GPS in sport included some consideration of spatial orientation, but it was more focussed on the mathematical skills involved in the process of data analysis and would not have improved spatial reasoning beyond that of a typical physical education lesson. However, the handling of real data in this activity was hoped to improve students’ attitudes towards the real world relevance of Mathematics outside of the classroom and to make some of the abstract concepts of the subject more tangible.

Table 10. STEM skill areas focussed on by activities at TICS

Activity	Spatial Reasoning Focus	Mathematics Thinking	Science Thinking	Engineering Thinking	Technology Utilisation	Group 1	Group 2
3D modelling	✔		✔	✔	✔	✔	✔
mBots	✔	✔		✔	✔	✔	✔
GPS in Sport		✔	✔		✔	✔	✔
Webpage Design				✔	✔	✔	✔
Adobe Spark					✔		✔

The impact of the visit to TICS on student attitudes

As attitudes are not unidimensional, differing aspects need to be considered when analysing the effect of the visit to TICS on student attitudes. In order to evaluate the effect of the TELE experience on student attitudes, a series of comparative analyses were undertaken to answer two key research questions.

Was there a change between pre- and post-TICS visit attitudes towards school subjects among Group 2 students?

Figure 26 shows a small variation in the underlying aspects of the composite attitudinal profiles of Group 2 students pre- and post-TICS. For example, these composite attitude scores for *Creativity*, *Enjoyability* and *Personal Usefulness* have visually improved between being measured before the visit to TICS and immediately afterwards. However, a one-way repeated measures ANOVA did not reveal any statistically significant differences between Group 2's pre- and post-visit attitudinal profiles.

A Wilcoxon rank sum test was used to identify any differences in the attitudinal profiles between Group 1 (measured a number of weeks after their visit to TICS) and Group 2 (measured immediately after their visit to TICS). This test was used in preference to ANOVA because the two measurement points were too far apart in time and the samples were unable to satisfy all the assumptions required for ANOVA. This test identified no statistically significant differences between the composite attitude profiles of Group 1 and Group 2 after their visits to TICS.

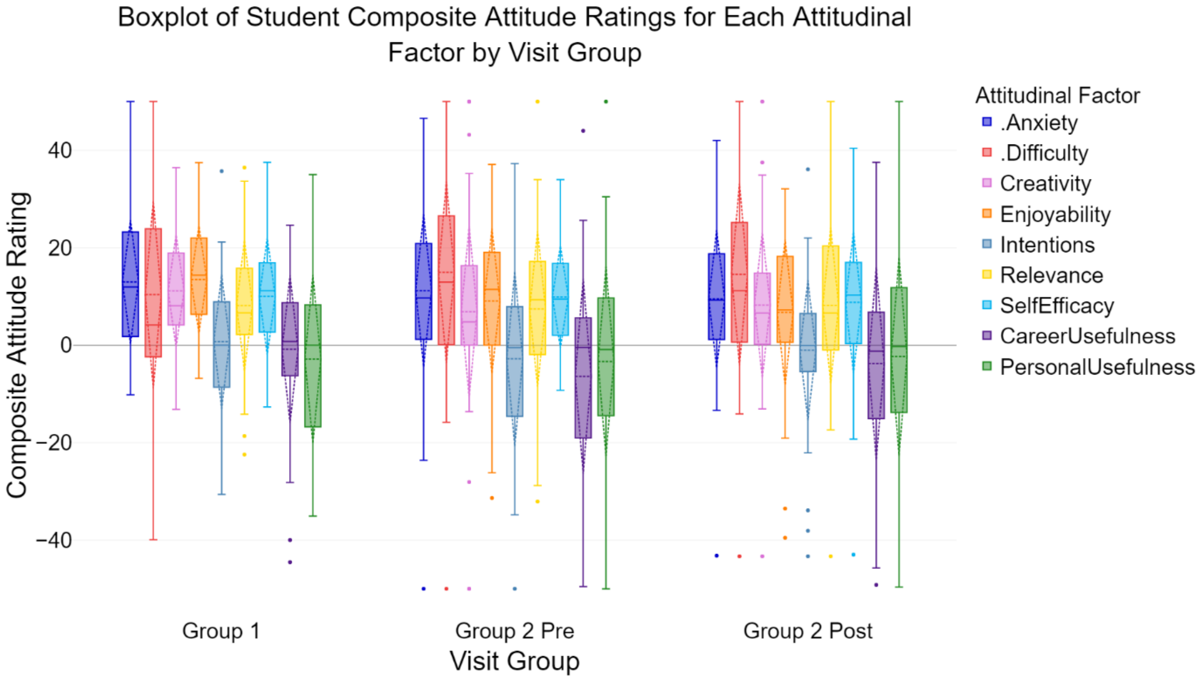

Figure 26. Composite Attitude Profile for participating students towards school subjects.
Visit https://schoolattitudes.unisa.edu.au/reports/NCSEHE to view this graph as an interactive

Was there a change in attitudes towards Mathematics for Group 2 after their visit to TICS?

There appeared to be some small positive changes in attitudes towards Mathematics following the visit to TICS by Group 2 particularly in regards to *Creativity*, *Self-efficacy* and *Career Usefulness* (Figure 27). However, a one-way repeated measures ANOVA revealed no statistically significant changes in students' attitude ratings towards Mathematics at the five per cent level for these visual changes.

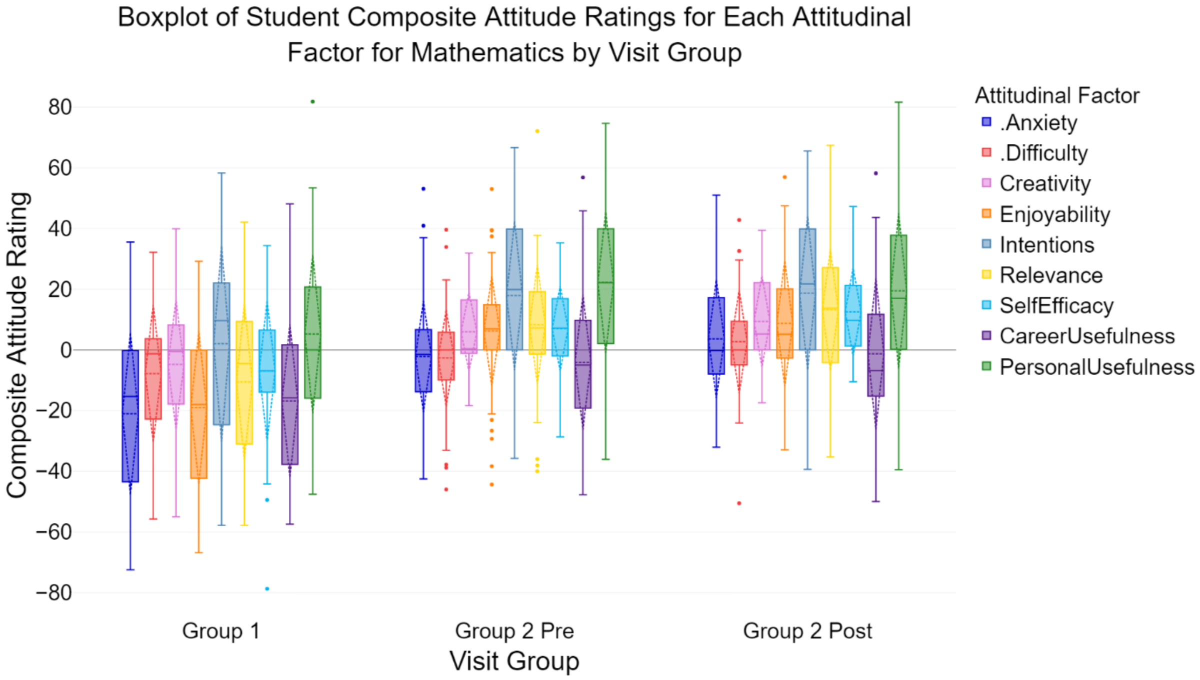

Figure 27. Subject Attitude Profile for Mathematics
Visit https://schoolattitudes.unisa.edu.au/reports/NCSEHE to view this graph as an interactive

A Wilcoxon rank sum test was used to compare the attitudinal profiles of Group 1 (measured a number of weeks after their visit to TICS) and Group 2 (measured immediately after their visit to TICS). This test revealed some statistically significant differences in the Attitudinal Profiles for Mathematics between Group 1 and Group 2 post-TICS visit:

- the median SAR for Creativity for Group 2 (*Mdn* = 6.98) was statistically greater than the median SAR for Group 1 (*Mdn* = 0.00) (W = 329, p = .004).
- the median SAR for Enjoyability for Group 2 (*Mdn* = 5.27) was statistically greater than for Group 1 (*Mdn* = -18.7) (W = 196, $p < .001$).
- the median SAR for Relevance for Group 2 (*Mdn* = 10.5) was statistically greater than for Group 1 (*Mdn* = -3.85) (W = 303.5, p = .002).
- the median SAR for Self-Efficacy for Group 2 (*Mdn* = 9.71) was statistically greater than for Group 1 (*Mdn* = -8.55) (W = 268, $p < .001$).
- the median SAR for Career Usefulness for Group 2 (*Mdn* = -5.41) was statistically greater than for Group 1 (*Mdn* = -19.3) (W = 351.5, p = .01).
- the median SAR for Personal Usefulness for Group 2 (*Mdn* = 16.1) was statistically greater than for Group 1 (*Mdn* = 0) (W = 373.5, p = .02).

Was there a change in attitudes towards Science for Group 2 after their visit to TICS?

Figure 28 shows the attitudinal profile of these student groups towards their Science classes at Corroboree Frog College. There are no visible changes in attitude profile for Group 2 pre- and post-TICS visit and a one-way repeated measure ANOVA revealed no statistically significant differences. A Wilcoxon rank sum test was used to compare the attitudinal profiles of Group 1 and Group 2 post-TICS and again no statistically significant differences in the attitudinal profiles were found.

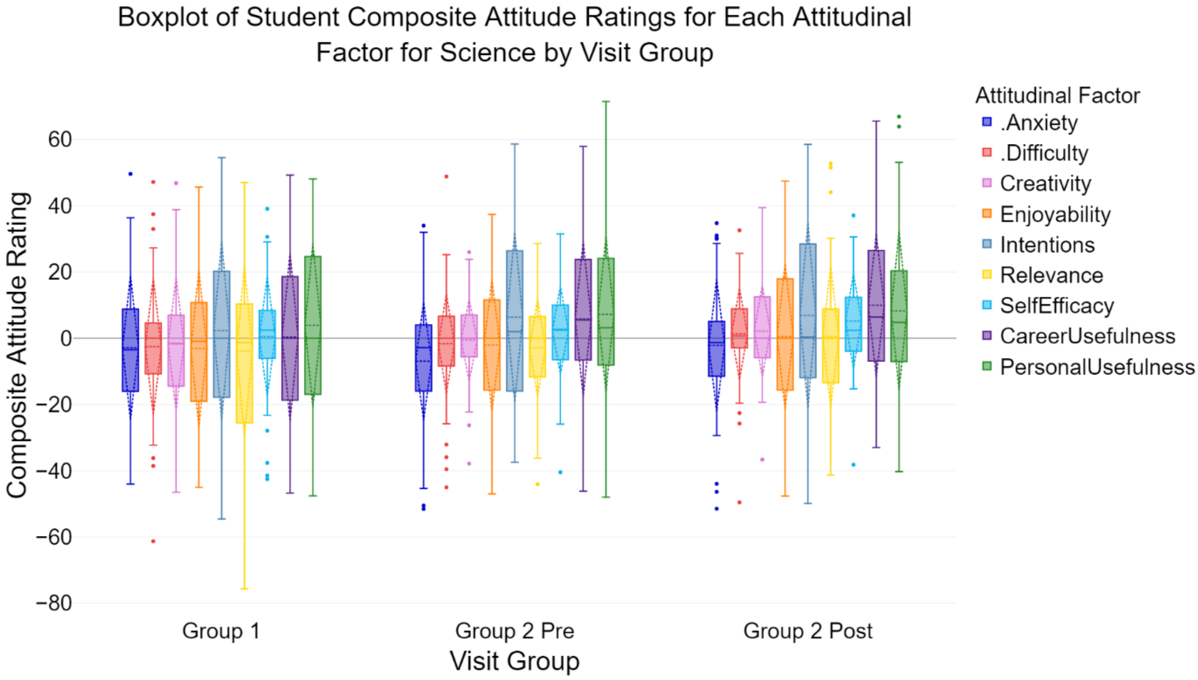

Figure 28. Subject Attitude Profile for Science
Visit https://schoolattitudes.unisa.edu.au/reports/NCSEHE to view this graph as an interactive

Discussion and conclusions

One of the goals of this case study was to determine the extent to which learning in an integrated TELE could change students' attitudes towards their distinct classroom subjects, in this case towards Science and Mathematics. The results from the SAS showed no statistically significant effect on students' attitudinal profiles. This is somewhat surprising as the spatial and computational nature of some of the activities did require students to make use of mathematical, scientific, and engineering thinking skills in solving the problems presented in the activities. There are a number of possible explanations for this observation. Firstly, the time of exposure to the activities at TICS were by necessity very limited. It is possible that this activity was thus simply too short in duration to have an effect on student attitudes in any way that was statistically measurable. This hypothesis is somewhat supported by the visible changes in the Composite and Mathematics Attitude Profiles but further research with a much larger sample is needed to investigate this further.

A second explanation for the lack of a change in attitude may be explained by the nature of the activities themselves. TICS is a TELE that is run by the staff of Corroboree Frog College and the activities were designed to primarily meet their learning objectives rather than our research foci. The activities were therefore focussed on a specific project at hand and did not require students to explicitly draw out knowledge and experiences from their specific subject classes, or return the knowledge gained during the visit to the TICS to their classroom subject. Again, further research using a series of more connected activities that are more narrowly focussed would allow the impact of TELEs on student attitudes to be better evaluated.

The statistically significant differences in the subject attitude profile for mathematics between Group 1 and Group 2 Post are interesting. The lack of change in attitude between Group 2 pre- and post-TICS suggests that the differences visible in the student attitude profiles towards Mathematics are more systemically embedded in the nature of Mathematics teaching and learning at the two campuses of the school. This difference in attitude towards mathematical thinking may underpin some of the different approaches to learning observed by the researchers and teachers present at TICS, particularly in regards to how students tackled some of the spatial reasoning problems presented to them in the robotics engineering and 3D modelling activities—an observation requiring further research to confirm.

While small, and not statistically significant, some of the observed attitudinal changes following exposure to TICS were quite promising. Students' observed levels of engagement when working within the TELE demonstrate the potential of similar institutes to increase engagement with STEM subjects, although longer periods of exposure may be required to improve results. Whether this novelty effect would continue requires more research, but it clearly illustrates the impact of environment on the mindset of students. Increasing levels of *Self-efficacy*, *Creativity* and *Relevance* to their lives suggests that a change in learning environment and approach may encourage learners who had previously negative attitudes towards school to be more open to the STEM fields.

Discussion of project findings

This project has established useful baselines on student attitudes towards school in general (CAP), and towards Science and Mathematics in particular (SAPs). The Year 6 to 12 baseline was developed in partnership with a very large school with a very diverse population that is broadly representative of the wider Australian population and these baselines were supplemented by data from another large school in Years 10 to 12. These baseline profiles show that **students hold generally positive views towards school even with the continuing uncertainty surrounding COVID-19**.

In establishing these baseline profiles, we found that ***Enjoyability*, *Relevance* and *Self-efficacy* are strongly correlated with each other across multiple KLAs** suggesting that these three attitudes may be subject to common influences. Furthermore, we have found that ***Creativity* is closely correlated with this triplet of attitudes** in both Science and Mathematics. This is a significant finding because, as noted earlier, *Creativity* is a teachable skill that might offer a viable pathway through which outreach programs may be able to influence and impact multiple student attitudes.

Case study 2 also showed that this triplet of attitudes remained strongly correlated and positive at both schools in this study indicating that they may be a source of resilience in learning. Higher education, and the pathway to it, requires this resilience. These attitudes may be particularly significant with respect to the 'gateway' subjects of Science and Mathematics. In the last decade or so these subjects have been subsumed into the 'STEM' agenda with its public discourse anchored on labour force needs and the 'jobs of the future'. What we have seen in this project, though, is that future workforce needs have a relatively low impact on students' attitudes towards a subject. An exception to this is in the negative sense that a decision to not pursue a STEM career does appear to cause a decline in the perceived *Enjoyability* of and *Self-Efficacy* in Science and Mathematics. These interactions are complex — the relationships between the constructs are not linear — and they need to be addressed together if we are to improve the equitable participation in the STEM fields.

Case study 2, showed that while many students in Years 11 and 12 elect to undertake further study in both Science and Mathematics, many students reported having more negative attitudes towards these subjects than towards their other courses. Specifically, Year 11 and 12 students reported being **more *Anxious* about Science, found the subject more *Difficult* and had lower *Self-efficacy*** than their other subjects. Year 11 and 12 students reported having **more negative attitudes towards Mathematics than their other subjects across multiple attitudinal factors**. While this case study showed that the triplet of attitudes described above continued to be positively correlated, we also found that subject *Anxiety* and *Self-efficacy* are, not unsurprisingly, strongly and negatively correlated with each other across both KLAs.

In case study 1 we noted that student **attitudes towards Mathematics, particularly *Anxiety* and *Self-efficacy* became lower as the student cohorts became older**. This was despite the implementation of multiple learning pathways in this KLA from Year 9 onwards that, in theory, should serve to reduce subject Anxiety and give students a sense of achievability. In light of the findings from case study 2, these observed patterns in the Mathematics attitude profile at Corroboree Frog College take on additional meaning. As a similar level of *Anxiety*, *Self-Efficacy* and *Difficulty* was also reported at Green Tree Frog School, then there is some evidence that at least **some of the underlying issues impacting student attitudes towards Mathematics may lie with the nature of the subject curriculum**. There are some other possible explanations for this observation such as the symbols of mathematics being more difficult to use in the online environment that was prevalent when we collected data, but there is likely more to it than that. In one of the schools, for instance, the decision was made to continue with handwritten work in most subjects so that students did not lose their handwriting skills for the end of year examinations. This meant that mathematics was not alone in moving to a practice of students uploading photographs of their handwritten work rather than using a computer to generate the text of symbols. Despite this, student attitudes towards mathematics were lower than towards other KLAs, which speaks to something about the pedagogical strategies of Mathematics. The nature of that ‘something’ is once again beyond the scope of this study, but this is an important finding as we look ahead to a world where online learning is likely to be a bigger part of schooling in general and even more so for particular equity groups like rural students.

Notably, case study 1 suggests that there may be an apparent **‘decision point’ for student attitudes towards science occurring late in Year 8 or early in Year 9**. Until this age the range of attitudes towards studying Science is reasonably consistent with students’ attitudes towards schooling as a whole. That is, while some students like school and others do not, they appear to like or dislike it as a whole. After late Year 8, however, there is a significant group of students whose attitudes towards Science, particularly their *Intentions* towards further study, becomes markedly more negative. Also worthy of note here is the widening of the range in reported attitudes in terms of *Intentions* and *Career Usefulness* (Figure 19). This suggests that at around Year 9 students are starting to narrow their career choices to the point that it does not include Science. This variance in *Intentions* and *Career Usefulness* is much lower in the later years of schooling where Science subjects are elective, and we can assume that many of those who do not see them as *Relevant* have simply not taken them.

Of greater concern around this Year 8/9 decision point, however, is the **decline in reported *Enjoyability* for Science** in the older cohorts. Basic Science is a gateway subject for an array of disciplines within higher education and is an important source of knowledge for navigating our complex and technological world, but there is a clear association in the minds of the young people in this project between *Intentions*, *Career Usefulness* and *Enjoyability*. This may reflect a negative consequence of the linking of career and education within policy discourses such as the STEM agenda and suggests a need for research on how we might maintain the enjoyability of subjects even when they have no direct career link.

Interestingly, the decision point we have been discussing in Science does not appear in the Mathematics data. This requires further investigation, but it seems likely that the decision point in mathematics is being reached earlier, before Year 6 who were the youngest cohort included in this project.

Beyond baseline measures, as we started to use the method in real evaluation contexts, the project reached some further important findings. As was reported in the third case study, **the SAS found no discernible change in underlying student attitude after a one-week program** in the technology enabled learning environment. This stands in contrast to the regular evaluation data—the post-activity survey—through which students reported the visit resulting in high levels of enjoyment, interest and motivation. Essentially, the students loved the week of activities playing with different technologies, but this did not transfer to any underlying change in attitude to their schooling or to any subject in particular.

This finding calls into question the validity of the ‘standard’ evaluation. It suggests that it may be measuring something like the ‘entertainment’ value of the activity rather than the deeper educational outcomes that the activities are seeking to instil. It also provides a strong basis for program improvement. If one week does not have a meaningful impact, then would two yield better results? Maybe programs could be conducted for one day a week over a much longer period? Perhaps there needs to be a deeper integration between the special program and the regular class curriculum?

Another finding from the third case study was that while the intervention did not appear to have a significant impact on attitude, the different cohorts engaging in the activity came with quite different attitude profiles. In this case we are looking at something quite like an experimental situation. The two cohorts came from two ‘schools’ from within the same collegiate organisation and sharing the same overall campus. The students at the two schools are drawn from the same community, and assignment to the schools is essentially random other than minor matters like siblings being matched to the same school. Given this near-random assignment, the different attitude profiles appear to be significant and suggest that the **different practices within the school are having different impacts on student attitude**. It was beyond the scope of this project to investigate these differences further, but the college will use this evaluative information and investigate this finding further.

Conclusions and recommendations

This project has demonstrated that "light touch" data collection systems like the SAS instrument can be used to provide useful and usable evaluative data in the secondary school context. As these techniques develop, they will provide the opportunity for educational designers, teachers, school leaders and policy makers to gain insights into different aspects of the complex activities of education.

In this project we were able to '*take the pulse'* of students' attitudes to each of their school subjects at different points in the school year at an almost negligible administrative cost. The participant cost of this has been a five-minute engagement during a pastoral care class for each collection.

The kind of data system we have built in this project is able to support the asking of fundamental program design questions such as duration, frequency, and foci as part of the educational design cycle. Realising this potential, however, requires something of a paradigmatic shift from the prevailing logic that the randomised control study is *the* gold standard for evidence in education. The current paradigm seeks simplicity. It seeks to isolate variables and test them one by one and, as we have discussed in the introduction, this means we end up overly focussed on the easiest variables to measure. We focus, for example, on changes in student's performance on basic knowledge or skills tests and so ignore the more expansive goals of education like shifting attitudes and aspirations. As we can see in this project, however, new technologies and new methodologies can provide ways to measure multiple factors within complex social systems. It allows us to move to a design-science paradigm rather than an experimental-science paradigm.

The project has shown that modern information communication technologies and advancements in research methodologies can be implemented in real-world settings to provide significantly different insights into learning programs and environments. It has also led to some important findings that can inform the design of programs seeking to promote equitable participation and success in higher education.

The key findings of this project may be summarised in the following seven recommendations:

Recommendation 1: Programs that aim to develop awareness of specific career pathways should be designed to appeal towards students in the early years of secondary school, or possibly earlier.

Case study 1 showed that for many attitudinal factors the range of attitude ratings increases as the age of students increases until the end of the middle years of school (Year 9) and then becomes slightly narrower again by Year 12. Of particular interest for programs aiming to develop specific career awareness is that students' reported *Intentions* to continue to study their school subjects decreased across year groups as the students age increased. As discussed previously the jump in *Intentions* seen between the Year 8 and 9 cohorts could be interpreted as a consequence of students being able to choose some elective subjects from Year 9 onwards; that is, they are able to elect out of some of the subjects they definitely do not want to study and that they had been reporting very negative attitudes towards in earlier years. In Years 11 and 12, while *Intentions* become more negative, students' ratings for *Enjoyability*, *Relevance* and *Self-Efficacy* do not. This supports the hypothesis that by mid to late secondary school students have formed ideas of which career pathways may or may not be suitable for them and they are expressing their *Intentions* towards their school subjects through this lens.

Recommendation 2: Programs that aim to develop positive attitudes towards school subjects should attempt to demonstrate the usefulness of subject content knowledge across a wide range of potential careers and also non-vocational contexts.

Case study 1 reported that composite attitudes for *Intentions* and *Career Usefulness* were more neutral than students' other attitudes towards school and that students' *Intentions* towards further study in specific subject areas were strongly related to subject *Enjoyability* for the late primary and early secondary cohorts. As discussed in Recommendation 1, students appear to be using their ideas about career pathways to shape their *Intentions* towards further study and thus it is important to emphasise the applicability and transferability of subject specific skills and knowledge to many possible career paths when designing and implementing programs aimed at younger students. If students are able to see the *Usefulness* of a particular subject to many career areas, then they may form positive *Intentions* towards that subject before their personal career directions begin to crystalise.

Recommendation 3: Programs that seek to impact students' attitudes towards school subjects should be domain (discipline) specific in focus.

We have shown in case study 1 and 2 that students' attitudes towards Mathematics and Science are quite different to each other. This finding, that students hold different attitudes towards the different domains of their curriculum, suggests that a one size fits all approach to designing learning programs does not exist across the different KLAs and that any potential outreach programs may need to be KLA specific or focused in terms of their learning objectives.

Recommendation 4: Outreach activities with the aim of increasing participation in Science might be most successful if they are implemented for students around 13 to 15-years-old and address both *Usefulness* and *Enjoyability* in their design.

The baseline data of case study 1 provides important guidance for programs seeking to improve participation and success in higher education. It tells us that in gateway subjects like Science, young people are making important decisions on their career pathway by around 15 years old, and that these decisions do have an impact on their ongoing attitude to different areas of study. The complex entanglement here cannot be understated and efforts to improve higher education pathways must engage with this complexity. These students' decisions are associated with a decline in *Enjoyability*, which is strongly associated with *Self-efficacy*. While it is difficult to construct causal models from this data, the associations can be considered in terms of identity. That is, we are seeing that there is a significant group of young people who, no later than Year 9, have decided that they are not good at Science, that they do not enjoy Science, and that Science has no use in their career future. As we have indicated, further research is needed to determine if there is a 'decision age' for students' attitudes towards Mathematics; however, if such an age does exist then the data in this study suggests that that age is even younger than for Science.

Recommendation 5: Programs that target older students' participation in mathematics should focus on communicating the relevance and interesting applications of the subject.

Case study 1 showed that Mathematics *Anxiety* steadily increased between cohorts as the students became older while *Difficulty* followed a more variable pattern. This suggests that the level of stratification in the Mathematics curriculum may have somewhat addressed the accessibility of the content for students, but the availability of multiple pathways has done little to address subject *Anxiety*. Looking at all the patterns together seems to suggest that students have heard the popular message that Mathematics is important for many future careers and that they *should* continue to study the subject at school. Yet, the data seem to suggest that as students become older, they find the subject increasingly less interesting, less relevant, and an increasing challenge to persevere with. It is therefore important that programs that target older students' participation in Mathematics should place a special focus on communicating the relevance and interesting applications of the subject to the students.

Recommendation 6: Programs that aim to impact students' attitudes of Enjoyability, Relevance and Self-efficacy should consider using *Creativity* as a driving principle during the educational design.

The triplet of attitudes *Enjoyability, Relevance* and *Self-efficacy* were seen to strongly correlate with each other across multiple KLAs and across both schools. In each case, the triplet of attitudes was seen to also corelate strongly with *Creativity*. This is particularly interesting because, while the triplet of attitudes measures value-based or perceived attitudinal constructs, our Creativity construct is action based. That is, creativity as defined and described in the introduction to this report is a teachable skill and practical approach to learning. Therefore, C*reativity* may have some potential to be a mechanism to affect the positive changes in students' attitudes towards their school subjects as discussed earlier and may in turn be able to assist in reducing subject *Anxiety* and students' perceptions of relative *Difficulty*.

Recommendation 7: Short duration programs need to be highly focussed if they are to have a measurable effect on student attitudes.

We showed in case study 3 that the SAS found no statistically significant change in underlying student attitudes towards Science or Mathematics after a one-week program in the technology enabled learning environment, TICS. The students engaged in four or five classes for just a few hours each, essentially sampling from the smorgasbord of activities available to them. The program as implemented by the teachers at Corroboree Frog College was not designed to focus on one specific skill, application or problem but was instead designed to expose students to a breadth of STEM skills. Future programs could benefit from this experience by remaining tightly focussed on the educational design stage if they are to have a specific and measurable impact on student attitudes.

Further research

While the findings in this report are significant, the full power of the approach taken in this project is yet to be realised. Further research working on longer time scales and across multiple schools and so using larger and more complex data sets is clearly warranted.

Of particular interest are studies that relate to two gaps identified in this project. Firstly, further research is required to understand how students' attitudes towards Mathematics change and develop in the primary years of schooling. This research is important because it will help in identifying the decision age, if one exists, regarding student attitudes towards Mathematics. Research is also needed to understand how the nature and implementation of the various Mathematics pathways and curricula in schools impacts on student attitudes towards the subject.

The second research strand relates to the evaluation of outreach programs that are designed to be implemented in TELEs. A larger sample replication study is needed to evaluate the effectiveness of short duration programs such as the one at TICS run in technology-enhanced learning environments. Further study using a series of highly connected, narrowly focussed activities is also needed to better assess the impact of technology-enhanced learning environments on student attitudes.

In all such future work, we must particularly begin to consider the support of professional learning for the educational designers, teachers and educational leaders accessing these new sources of evaluative data. The data we have been working with in this project are not 'better' than traditional evaluation data, they are qualitatively different. They change the *kinds* of educational question that can be asked. When we ask 'is this educational program good for students', our definition of 'good' is shifted by the kind of data we are working with. This suggests a need for a serious consideration on the ethics of how this data is used to represent the learning environment. As the rise of the conspiracy theory on social media has shown, who controls representations or truth—and who we trust to mediate those representations—are not trivial matters. The data tools we have used in this project are here now, so the ethical work is urgent.

A promising approach to this professional support that we are exploring in other projects is to provide this support through networked professional learning. In this model, we are providing teachers with access to the kinds of data we have used in this report and we are asking them to use that data to inform their work on real projects within their school. We are supporting this work by facilitating a peer-evaluation of the work so that teachers can work with other teachers to better understand what the data is showing them, and by providing a virtual space for teachers to reach out to our research team and to co-construct interpretations of the data.

Having emphasised the need for caution, we conclude though by highlighting the promise of the work outlined in this report. Education is complex, but our evaluation methods have struggled to adequately deal with that complexity. As this project has shown, new methods can change this. New methods can put powerful data into the hands of professionals and provide important insights into factors that matter when the goal is to widen educational participation and success.

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