Chapter 7
Progressing STEM Education Using Adaptive, Responsive Techniques to Support and Motivate Students

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Abstract The components of a series of workshops in science, technology, engineering and mathematics (STEM) for Indigenous school students, conducted by the Mathematics Learning Centre (MLC) in conjunction with the Faculty of Engineering and Information Technologies at the University of Sydney (UoS), are described. The MLC has developed and taught the mathematics component of these STEM workshops in 2017. This chapter builds on Phillips and Ly (2020). The STEM workshops have been developed using a distinctive, innovative approach that has drawn on the experience, knowledge and philosophy of the MLC, as well as the key pillar concepts of cultural competence, advanced by the National Centre for Cultural Competence at the UoS. How these concepts have been progressed to the principle of cultural plasticity is discussed in the context of the MLC and the STEM workshops. Our approach has been to give the students a genuine voice in their own learning experience and is encapsulated in the themes of 'knowing' and 'responding'. These themes and their connections to cultural competence and cultural plasticity are discussed. We also describe how these themes have been employed. Input is encouraged from the students through surveys before, interactions during and feedback after the workshops. How this feedback has been used to evolve, progress and improve the workshops over the three-year period is then described. In particular, the students have identified interest in some motivational topics as well as a desire to explore certain mathematics topics from school. The principles of knowing and responding are demonstrated in both the inclusion of motivational topics, and subsequently, the evolution of these (along with other) topics through continuous improvements from the students' input. This evolution is outlined in the context of the motivational topic of *Codes and Code Cracking*. This has been used to explore advanced ideas and concepts in the mathematical realm that may be beyond the students' current experience. The response of the students to the STEM workshops and the use of the programme more widely is also described. Throughout the article we provide reflections on our experience with the workshops in the light of offering insights that may be used as a resource for future initiatives.

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Introduction

Some of the key pillar concepts of cultural competence have been at the heart of the philosophy of the Mathematics Learning Centre (MLC) at the University of Sydney (UoS) from its inception in 1984. Because there is no obligation for students to attend the MLC to satisfy any part of any course at the UoS, the MLC must be adaptive to individual needs and perspectives, responsive to changing modes of learning, receptive to a broad spectrum of cultural worldviews and inputs, and culturally responsive, for any student to continue engaging with the MLC.

The National Centre for Cultural Competence (NCCC) at the UoS has informed and advanced the use of cultural competence in the MLC. Both the pre-existing philosophy of the MLC and the work of the NCCC have been instrumental in developing and improving a workshop programme to engage, improve and motivate Indigenous participation in science, technology, engineering and mathematics (STEM) at the UoS. The MLC joined the Faculty of Engineering and Information Technologies (FEIT) at the UoS to provide the mathematics component of these STEM workshops in 2017. Throughout this chapter we refer to the mathematics component of the STEM workshops as the workshops for brevity. These STEM workshops are run as week-long intensive programmes for Indigenous school students from across Australia. The details of the first year of the programme are presented in Phillips and Ly (2020). The current work reports on the progress, evaluation and evolution of the workshop programme.

In this work we outline how the philosophy of the MLC and the pillar-concepts of 'perspective', 'worldview' and 'resilience', as outlined and developed by the NCCC, have contributed to the development of the workshops. For us the philosophy and pillar-concepts of the NCCC and MLC intersect at key principles. These include the importance of the perspective of the individual, knowing the student worldview and responding in a way that addresses the student's individual resilience and ensures they can feel safe and supported.

Distinctively, we recognise that STEM may have its own cultural elements and that in the process of learning STEM an amalgamation/blending of cultures can take place. Consequently, it has been necessary to expand upon the key pillars of cultural competence to consider or allow for this possible amalgamation in our own approaches and attitudes to teaching. We shall refer to this quality as cultural plasticity, which is defined as being receptive to, learning from and adapting to the cultural perspectives of others (Phillips & Ly, 2020).

In contrast, *cultural rigidity* is the inability or refusal to be receptive to, learn from, or adapt to the cultural perspectives of others. An individual can certainly exhibit cultural plasticity, but this can also be adopted by a group or be a quality of an environment. The details of this concept, and how it has affected our interactions with students will be expanded upon through this work.

Implementing and Fostering Cultural Competence

In this section we demonstrate how key concepts of cultural competence have affected, informed and been fostered at the MLC and the workshops. In particular, we discuss the concepts of the perspective, worldview and resilience.

Individual Perspective and Worldview

> Every one of us is born into a particular time, place, social context and culture. In fact, we see everything through the filters of our culture and experiences; and our ideas, views, opinions and behaviours are not 'objective' and independent… (NCCC Cultural Competence Module 1.2, Journey of Self-discovery: Worldview)

The MLC has supported a culturally diverse student cohort from its inception including the support of Indigenous students. The MLC was established in 1984 (the first such initiative in Australia) and from its outset has supported students of educationally, socially and culturally diverse backgrounds. Thus, at the MLC we recognise that 'people bring different ways of knowing, being and doing' (Excerpt from NCCC Module 4, Know your world, See my world.). Consequently, the principle of being responsive to an individual's perspective and worldview has been at the core of the MLC from the outset. This can be emphasised by the fact that many, if not most, of the students of the MLC would have tried the mainstream forms of learning and found them insufficient. Often this is because some of the conventions, norms, values, pre-suppositions, language and ideas of the conventional mathematics classroom or learning channel may not align well with their own perspectives. For example, a student may, for whatever reason, find it difficult to appreciate how a presented solution is the 'best' solution, yet is able to arrive at a solution using an approach that from their viewpoint may be more natural and plausible. What is 'best' can be contingent on attributes such as 'succinctness', 'beauty', 'rigour', 'insight', 'elegance' which are, arguably, cultural elements of the discipline. Indeed, even what constitutes a 'proof' in mathematics has evolved over the centuries. It is important that such viewpoints not be disparaged or dismissed. Even for practising mathematicians, it is generally acknowledged that there is a diversity in perspectives, which is not only accepted but recognised as fruitful for the discipline. For example, some researchers may prefer a visual-spatial approach to their work, while others prefer the so-called 'analytic' approach. These differences in approach are part of what Burton (2009) calls a 'heterogeneity' in research practice. It has often been the case that a new perspective has transformed the discipline.

Thus, at its core, to operate effectively the MLC must be culturally respectful, responsive, resilient and agile. Since participation in our services is completely voluntary, the fact that students continue to return to the MLC is strong evidence for the effective implementation of cultural competence. We attempt to accommodate, respond to and support different perspectives at the MLC through two interrelated themes. First, we seek to *know the student* by acknowledging that, 'at the heart of any culturally responsive teaching programme is a genuine knowledge of the students and their needs', albeit recognising that this knowledge is 'often determined by the worldview held by the teachers' (Perso, 2012, p. 30). Secondly, we also acknowledge that:

> culturally responsive teachers *respond* to the cultural knowledge, prior experiences and performance of students to make learning more appropriate and effective for them. They teach to and through the strengths of their students, reducing the discontinuity between the home cultures of these students and the social interaction patterns of the classroom (Boon & Lewthwaite, 2015, p. 456; paraphrasing Gay, 2000).

In this sense we also attempt to *respond appropriately*.

Knowing and Responding at the Mathematics Learning Centre

> Recognising that people bring different ways of knowing, being and doing is important if we are to find ways to include culturally informed ways of learning and working together (NCCC Cultural Competence Module 4; Know your world. See my world.)

Knowing and responding play important roles in cultural competence, since developing an awareness of how you and others around you perceive the world can have a crucial impact on your interactions. Our experience in knowing and responding in the context of the MLC is outlined below. We begin to know the student during our enrolment process. This includes an informal interview followed by the student completing a short enrolment form. Here we seek to gather information about the student such as any past mathematics courses, where and when they have studied mathematics, the degree in which they are currently enrolled and why they think they need our help. The students have the opportunity to provide any cultural information at this stage, however, this is completely voluntary.

Even though the information gathered during the enrolment process is valuable, interactions in the classroom are the principal means of knowing and responding to our students. These include observing each of the student's individual modes of learning, how each student interacts with other students and our interactions with each student. Knowing the student informs how we respond. By considering their experience and background, we may tailor and design explanations or examples for each individual student that are different to those available in their standard courses.

Here we give examples of how some of the MLC students' prior experiences can inform our teaching. Some students identify that they have missed a section of mathematics because of being sick, moving schools or some other circumstances beyond their control. Many have also cited having a 'bad' teacher as the crucial factor. Past teachers could make them feel inadequate or even stupid with comments like, 'you should know this', 'this is trivial' or even just using words such as 'easy', 'obvious' or 'simple' to describe new mathematical ideas. In these contexts, students can conclude that they could not ask the questions they needed to for fear they would be regarded as 'stupid questions'. Past and current learning environments could also have had a negative impact. For instance, many of our students feel that in the past there was little opportunity for them to have input into their learning in teacher-led classes or in group learning modes when other students dominated discussions. All these factors can contribute to the accumulation of gaps in their mathematical understanding and knowledge. Moreover, many students at the MLC feel there is little opportunity in the mainstream classes to learn or shore-up foundational concepts, and because mathematics builds on past concepts, perhaps more than any other subject, this inability to shore-up foundations leads to more unstable learning that compounds or exacerbates any anxiety towards mathematics they already feel.

These are just some of the ways that past experiences can affect present mathematical learning and, although not obvious, these experiences and perspectives can be intimately linked with culture. Different students from different backgrounds will have different perspectives of what is appropriate behaviour in different learning circumstances. Thus, learning environments will affect each student differently. There are increasing discussions in the literature on the cultural and social structures embedded in the teaching and practice of mathematics (Aslan Tutak, Bondy, & Adams 2011; Averill et al., 2009; Burton, 2009).

Knowing all this, our response is to try to provide a safe, non-confrontational, environment where students feel they can share their past experiences. Many of our first contact sessions with students involve just listening to a student's past experiences, associations and even traumas in learning mathematics. Often this may help the student to dismantle some of these past anxieties or traumas. This process can be transformative.

> Sometimes using words like "this should be easy" or "obviously this follows this" can make you feel as if there's something wrong with you since it wasn't "easy" or "obvious" for you,. … It can feed into other insecurities that you might have about your ability, whether you belong there etc. The biggest difference with the MLC was that I felt the tutors were empathetic in their teaching style and were patient enough to understand what it felt like to me to not get it. (communication from past MLC student).

One of the main operating principles of the MLC is that there are no stupid questions. This means we will help with foundational concepts, going as far back as necessary. As one past student comments about the MLC: 'It was extremely healing for me and I felt safe in that space to ask questions that I normally would be ashamed to ask in a lecture'.

Another operating principle is that rather than just referring the student to a *standard approach*, we first attempt to understand a student's approach in solving a problem or understanding concepts. This is another way of 'knowing' the student. We can then respond by attempting to work on the problem together by using their 'tools' of thinking. This cooperative process can highlight mistakes, uncover misconceptions or even (delightedly) reveal a completely new solution method. Importantly, it also provides a way for the student to reconcile their individual thought processes and perspectives with standard approaches. There is a growing body of literature on principles of good practice in mathematics support that the interested reader may consult (e.g., Croft et al. (2011). These principles of knowing and responding have significantly informed our teaching in the workshops.

Knowing and Responding in the Context of the Workshops

In approaching the workshops, and with respect to the themes of knowing and responding, it was considered vital to:

- remain aware that cultural perspectives are individualised and that each person (course coordinators included) perceives their reality through their own unique cultural perspective; and
- provide a means whereby the students can provide feedback about their background and perspectives.

Additionally, by inviting feedback from the students we were able to demonstrate our interest in the backgrounds of the students and indicate that we wanted to provide a responsive and supportive learning and teaching environment. Thus, as the first step we asked the Faculty of Engineering and Information Technologies to survey the students about their home state and what level of mathematics (if any) the students were studying at school. The course designers considered it critical to provide an avenue for students to have an input into the mathematics workshop. We also thought it is important to understand the different dimensions of the students. Not only was it important to know the students' backgrounds, but also what the students thought they needed help with, as well as their understanding, confidence and interests. For this reason, to gain a better understanding of their needs, wants and perspectives, each of the students (in the first two years of the workshops) was asked to respond to a survey. The survey asked the students to identify the topic in mathematics that they thought may be most useful or interesting. Some topics were listed as options, but they could nominate any topics they liked. The students were asked to rate the difficulty of a mathematical question to get an insight into their mathematical backgrounds. The students were also asked to gauge their overall confidence in mathematics. All of these details were used to design the workshops. Details of this survey process (including results) are given in Phillips and Ly (2020).

Perhaps most importantly, the process of inviting the students for their input and then using this input to design the workshops and interactions throughout the workshops indicates to the students that their input is not only welcome but is valued in the learning and teaching process. In this way the key elements of 'receptiveness', 'learning from' and 'adaptation' of cultural plasticity have resulted in the students' roles in the workshops evolving from just being recipients of knowledge to being active participants and evolving further to being co-conveners or co-producers of their own learning.

Resilience

> Resilience… is the ability to go through something and then start to recover. Cultural competence requires people to build resilience… Very importantly, by developing your cultural competence you will be less likely to harm people who are perhaps less resilient or have had more trauma than you have by being culturally insensitive (NCCC Cultural Competence Module 1.3, Journey of Self-discovery: Resilience).

One of the chief aims of the MLC is to build student confidence in their mathematical abilities and this can be critical to a student's progress in their studies. The process of studying mathematics often involves facing disappointments, setbacks, failures, dead-ends, mistakes, and trying again (perhaps with a different approach or different perspective). Thus, in the first instance, we observe a link between confidence and resilience (in mathematics).

Secondly, sensitivity and responding carefully to those with lower confidence (or resilience) in mathematics is one of the core principles of the MLC. The authors estimate that approximately fifty percent of the students seeking first time help at the MLC may harbour concerns, fears or even trauma associated with prior engagements with mathematics. Many of this cohort have sought the support of the MLC specifically because within the standard learning channels there may be little help or acknowledgement available of past or present fears of the mathematical sciences. At the MLC it is critical to acknowledge and remain receptive to such trauma. For instance, for some of our students who are stressed or even traumatised, the worst first approach would be to try to teach mathematics or statistics without talking about past troubling experiences. Often, we need to allay fears and possibly address past trauma before engaging in any learning material. MLC teachers are knowledgeable about referring students to counselling services, and often students, after experiencing the support of the MLC, will volunteer that they have subsequently sought counselling or disability services.

Relentlessly, and possibly unconsciously, demanding a student face mathematics before addressing their fears and concerns can increase and compound fear and trauma for the students. This principle has also been pivotal in our approach to the STEM workshops. Our research into the workshop students' backgrounds revealed that their previous school studies ranged from Year 9 to Year 12 from schools across Australia. For this reason, and from the individual pre-workshop surveys, the teachers of the mathematics component of the workshop decided that there should be two separate curriculum streams for the topics of *Algebra* and *Calculus*. This way pre-calculus students (predominantly from Years 9 and 10) could opt into the *Algebra* stream, whereas students at a more advanced level (predominantly from Years 11 and

12), could choose to engage with the concepts and practices of differential calculus, albeit at an introductory level.

For us, *insisting* that a Year 9 student attend a workshop session that required a further two years of mathematical study of calculus is unacceptable. The course coordinators wanted to avoid at all costs any such student surmising, incorrectly, that they were not 'good enough' to continue with mathematics or even that university or STEM was not for them. To provide only one form of curriculum support for these students would have been insensitive and incompetent on our part and quite possibly produced harm or even trauma.

Fostering Cultural Competence Amongst Students

The learning environment of the MLC is one that is conducive to developing and growing student cultural competence. First, students of different ages, cohorts, backgrounds, cultures and worldviews, who may not otherwise interact with one another (either by choice or by lack of opportunity) come together at the MLC to work and support each another in a community. At the MLC the students (and, of course, the teachers) are continually exposed to different perspectives, worldviews and different approaches to learning, as well as different approaches to mathematical problems. Such different approaches can cultivate a receptiveness to other perspectives, encourage self-reflection and thereby foster cultural competence. Secondly, the support and encouragement of the students' peers and the teachers at the MLC can mean the difference between giving up or trying again. As students consistently engage and re-engage with their learning, their confidence (resilience) can grow, which could have an impact on not only their performance but other areas of their lives. Thus, the environment of the MLC provides ample opportunity for students to develop and grow in cultural competence.

The Need for Cultural Plasticity in Teaching and Learning

> Culture is the learned and shared knowledge that specific groups use to generate their behaviour and interpret their experience of the world. It is a defining and vital aspect of every human being. Every culture has its own standpoint or worldview that informs our ways of thinking, and how we behave and act. (NCCC Cultural Competence Module 1.2, Journey of Self-discovery: Worldview)… each discipline has its own knowledge system as well the knowledge systems that individuals bring to their studies and workplace (NCCC Cultural Competence Module 4; Know your world. See my world.)

It has been contended that learning mathematics at times necessitates conceptual changes, or perspectival shifts to make progress (Breen & O'Shea, 2016; Cobern, 1996). Some familiar examples may include the concepts of functions, limits and costs and quotient groups, as discussed in Breen and O'Shea (2016). Since mathematics provides one way of looking at, organising, and thinking about reality—if not explicitly, then perhaps implicitly through the fact that so many other disciplines draw upon mathematics—it is conceivable that this shift can affect one's worldview, whether consciously or unconsciously, for better or worse. Indeed, words associated with threshold concepts in the literature include transformative, troublesome, irreversible, which seems to indicate a more profound effect on a person than a mere acquisition of knowledge. Thus, while educators often require and desire their students to undergo such conceptual changes it is worth noting that the process can be empowering but also possibly uncomfortable and difficult for the student, depending on their own worldview and identity.

It is also often recognised that there are cultural elements associated with mathematics. In her interviews with a group of mathematicians, Burton (2009) has identified some cultural elements of mathematics and classifies these elements into either the mathematical culture which is 'the environment in which the mathematics is encountered and learned and inevitably influences the culture of mathematics' (Burton, 2009), or the culture of mathematics, by which she means:

> those aspects of mathematics that are recognisably discipline-related (such as the particular attitudes towards beauty, rigour, structure, etc.). Learning the importance of these aspects of the culture of mathematics is part of induction into the mathematics community of practice.

To the latter we could perhaps add attributes that could be associated with science more generally, such as reproducibility, refutability, proceeding from a set of axioms or postulates, internal consistency, and even being receptive to a new concept unless and until it is disproven.

Whilst students need to embrace new concepts and ideas as part of the process of learning mathematics, we also wish to recognise that the student may also need to navigate (and perhaps absorb) an array of, perhaps unspoken, cultural elements associated with the discipline. For instance, the concept of a limit may have associated notions of rigour and succinctness that we are expecting students to assimilate implicitly, if not explicitly. Furthermore, although students can merely tolerate or endure mathematics, mathematical educators often rightly or wrongly, consciously or unconsciously, desire their students to embrace, engage and perhaps adopt some of the worldview and cultural aspects of the discipline into their own lives. In effect then, we are asking for a sense of 'plasticity' in the students, that is, an 'open-ness' on their part to the expanding and embracing of new perspectives. The term 'culture acquisition' has been sometimes adopted (Aikenhead, 1996), but we prefer the sense of open-ness to change that 'plasticity' suggests. However, we suggest that sometimes such cultural elements can be their own barrier and that a kind of plasticity on the part of the educators themselves, and thus of the classroom as a whole, can be productive and reduce barriers.

Here we offer a few examples of how this may occur in the context of mathematical teaching and learning. Students often bring different ways of approaching their work, for example in organising, writing, thinking and speaking. A student may prefer to use certain symbols or may present a calculation in a long sequence of steps that may be ‘inelegant’. For the purposes of instruction and at least in that learning environment, it could be productive to adopt the students’ approach and attempt to operate and teach within the students’ world. Thus, awareness of one’s own cultural perspectives and a willingness to embrace the students’ perspective may be needed. In essence, as much as possible, we are seeking to ensure that we ourselves are not barriers to our own message, and that as much as possible the students can engage with the discipline on its own merit. It is worth recognising at this point that science has itself been through such a plasticising process: ‘Western science itself has gone through a process of philosophical and methodological evolution in which some of the underlying principles have given rise to different visions of scientific knowledge’ (Pomeroy, 1994, p.65). This is as a result of having embraced and adopted perspectives and elements of different cultures and worldviews from around the world throughout time.

To appreciate how we have employed cultural plasticity in our teaching and learning contexts, it is important to understand the central role that the individual plays in each of those contexts, and it is this aspect that we turn to next.

The Role of the Individual and Cultural Plasticity

As we have alluded to earlier, responding appropriately to the individual needs of a student is an important aspect of the MLC. Here we discuss how this view is reflected in the literature. For many of the students, who seek the help of mathematics support centres, the standard Materials and methods of delivery have not adequately worked for them. This is largely because such material and its delivery are primarily designed for the ‘traditional student’, that is, those students entering tertiary education with a certain level of school education straight from schooling in the local system, who may also be from an assumed ‘traditional’ background. However, the broadening of participation of students with non-traditional backgrounds entering university has resulted in a ‘much greater diversity of numeracy, mathematical skills and knowledge backgrounds across tertiary cohorts’ (MacGillivray, 2008, p. 13). Consequently, a one-size-fits-all approach is becoming less appropriate and there is an increasing pressure to provide more diverse teaching material, lesson delivery and modes of learning, as well as an increased need for extra-curricular mathematics support.

Indeed, the literature on mathematics support recommends good practice as providing a tailored, individual, ‘person-centered’ approach (Croft, 2011; Delderfield et al., 2018). This is summarised well by Patel (2011) in her study of the effectiveness of various approaches to mathematics support:

> The individual occupies a key position in mathematics support since the student’s very specific mathematical skills needs are addressed (Samuels & Patel, 2010). Situating the individual at the heart of learning is desirable as learning theories have highlighted. (Patel, 2011, p. 15)

Likewise, the importance of individuality occupies an important part of culturally responsive pedagogy for Indigenous students. It is recognised that:

> one approach to culturally responsive pedagogy that works with one Aboriginal student may not necessarily work with another (Krakouer, 2015). Consequently, any framework for culturally responsive pedagogy with Aboriginal students' needs to consider the individuality that rests within all students as well as within and between Aboriginal language groups. (Daniels-Mayes, 2016, p. 53)

Indeed, Perso (2003, 2012) in her discussion of pedagogy for Indigenous school children—whilst recommending useful behaviours and practices for the classroom—nonetheless observes that:

> If over-generalizations are made about the preferred learning styles of Indigenous and minority children, there is a risk of stereotyping. What can result is a biased pedagogy that may result in the needs of some children not being addressed through the pedagogies used. Just as there are many Indigenous cultures, so there are many Indigenous learning styles (Perso, 2012, p. 51)

She advocates that to be effective in such contexts, teachers need to 'learn and know' about, and 'respond' to each individual student. It is now generally recognised in the literature that knowing and responding to the individual are important components of any culturally responsive pedagogy (Paige, Hattam, Rigney, Osborne, & Morrison, 2016).

The above discussion reinforces our perspective that the role of the individual is critical in all of the spheres in which the MLC operates. In the STEM workshops this is further accentuated by a number of factors. First, the students in the workshops travelled from different states across Australia and thus belong to different Indigenous communities. Furthermore, the students are of different ages, have had varying levels of, quality of, and even access to, education, and also have different mathematical backgrounds. This wide diversity only reinforced the importance of maintaining the needs of the individual at the core of the workshops. Whilst we could have concluded that it is too difficult to accommodate the 'sheer diversity' of our students, we thought that the small class sizes meant that we should try to respond to each individual student's perspective. We did this by inviting feedback and allowing each student a voice throughout the workshop. In the process, personal viewpoints about STEM were considered, the teachers could also re-evaluate and possibly become aware of their own pre-suppositions in their instruction (and readjust their approach if needed). Furthermore, any common (cultural) elements amongst the group can be picked up and the class can be adapted around this element.

'Knowing' and 'responding' to the individual, therefore, is how we have employed cultural plasticity and in the next section we discuss how such principles informed and improved the motivational cryptography sessions.

Cultural Plasticity in the Cryptography Sessions

In this section we aim to demonstrate how we have employed cultural plasticity in the workshops, specifically through the themes of knowing and responding to the individual. To this end we outline how we have responded to the individual input and perspectives of the students in the motivational sessions on *Codes and Code Cracking*, and how these sessions have been shaped by their input.

First, cryptography is not a core topic of the HSC curriculum in most states of Australia. Prior to the workshops in 2017 and 2018 we asked the students through a questionnaire, 'What mathematical topics do you think would be most useful or interesting?'. While there was no restriction on the topics the students could nominate, to encourage responses, the topic of *Codes and Code Cracking* was included as one of the suggestions. This topic was consistently nominated in the top two topics along with HSC curriculum-based topics such as Algebra and Differentiation. For this reason, and from the feedback of the students during and after each of the workshops, the cryptography sessions have formed a major component of the workshops.

The process of seeking and acting on the feedback from the students demonstrates a genuine attempt for us to know and respond to the students. Rather than pre-supposing what an (Indigenous) school student may, or may not, be interested in, we allowed each individual student to speak for themselves. We believe this also established from the outset a cultural element of listening, learning and adapting to student feedback.

Knowing and responding continued throughout the workshops and impacted the modes of learning and how the core concepts of cryptography were conveyed. The modes of learning evolved considerably, both during and from one workshop to the next. For example, the students responded enthusiastically to discussion about where codes have been used, and it was clear from the first workshop that the students were very interested in how cryptography played a significant part in World War II. Indeed, some of the students already knew about details of the German 'Enigma' machine and its flaws. In response to this enthusiasm and prior knowledge, these discussions were increased at each subsequent workshop and even incorporated a short YouTube clip from *Flaw in the Enigma Code* (Grimes, 2013).

We note that this prior interest and knowledge is resonant with the fact that 'high-performing' Indigenous students tend to report higher levels of engagement with out-of-school STEM activities (in comparison with all Indigenous and non-Indigenous students) as some have observed (McConney, Oliver, Woods-McConney, & Schibeci, 2011; Woods-McConney & McConney, 2014). Although such a prior interest (as a common cultural element amongst the group) could be surmised from the programme selection process, it is important to note that we did not assume this would be true for all the students, choosing rather instead to let the students indicate and express their individual enthusiasm and prior engagement in person. As another example, in the Rubik's cube motivational sessions in 2017, some of the students surprised us by demonstrating a facility in 'solving' the Rubik's cube prior to attending our sessions.

We responded by encouraging these students to participate in the teaching through sharing their expertise, as well as leading and supporting their peers.

How the sessions engaged with the core concepts of cryptography also evolved through responding to student input. We decided to adopt the Vigenère cypher method, since we felt this method could demonstrate the core concepts of cryptography effectively and appropriately. In its simplest form, encoding and decoding a message using this method involves shifting letters by a pre-determined shift. To encode a message with a '*1*-key' of 'shift k', each letter in the message is replaced by a letter that is k places along the alphabet, with the convention that A is the next letter after Z. For example, for a '*1*-key' Vigenère cypher of 'shift 3' then the 'message' *HAL* is encoded as *IBM*.

Originally, we asked the students to encode a message by shifting the letters of a message along the alphabet and then decoding the resultant code by shifting the letters in the code 'backwards' to recover the message. We responded to the enthusiasm of the students by incorporating a Socratic exchange with questions such as, 'If you were given a code that was encoded by shifting the letters in the original message by a fixed shift, how would you try to guess the shift and then crack the code'? To promote thought about how to do this, a histogram of 'standard' English text (Appendix 1) was also given to the students. Subsequently, the discussions concluded that to decode a message we could find the most frequent letter in the code and compare this to the most frequent letter in the English language (being the letter e), and or produce a 'graph' of the letters in the code and compare this with the histogram of 'standard' English text (as given).

Another example is how we might increase the difficulty of decrypting a message. Originally, we simply explained the concepts of a multi-key cypher to the students and asked them to crack a code using this method and the shifts that we gave them. However, after observations and feedback from the students it was decided that we should ask the students: 'If you can crack a 1-key code by using the histogram approach, and guess the (single) shift, how could we make a message harder to crack'? The students readily answered that we could use different shifts on different parts of the message. The discussion then continued that using different shifts on different parts would 'blur' the distribution of letters in the code, so it will look different to the standard English distribution.

This way of demonstrating the concepts using a Socratic exchange with the students allowed them not only to 'discover' the concepts themselves (and thus 'adopt' or take ownership of the concepts), but to express it in their own perspective. In particular, if their responses did not include discussions around producing a graph, then that would have told us something about their perspective on the topic, and we would have had to modify the subsequent activities accordingly. Other improvements we have made in response to the input of the students include a redesign of the set of exercises. For details see Appendix 2.

The examples above illustrate the two-way process of learning and growing (by teachers and students alike) through knowing and responding. In this regard the cultural growth of both the students and the teachers is facilitated and improved by exploring together the new techniques, concepts and culture of the mathematics.

We would like conclude with the following observation: in each workshop (as in the cryptography section) participation evolved to the point where students, teachers and ‘house-parents’—volunteers who accompanied the students through all of the STEM workshop programme—adopted ‘cooperation over competition with a preference for cooperative and collaborative learning’ (Boon & Lewthwaite, 2015; Duchesne, McMaugh, Bochner, & Krause, 2015). In this sense, the group adopted a learning model embracing cultural plasticity. Thus, cultural plasticity can be embodied not just in individuals, but within a learning environment.

Summary of Survey Results from the Workshops

Here we provide a summary of the survey results across the three-year period from 2017 to 2019, with a more detailed analysis of the 2017 results in Phillips and Ly (2020).

The students were asked to rate whether and how their understanding of the subjects taught in the workshop (curriculum and motivational topics combined) had changed (Table 7.1). The Faculty of Engineering and Information Technologies (FEIT) also asked the students to rate the different components of the whole STEM workshop programme using a five-point Likert scale. The students' satisfaction with the mathematics component of the workshop are as follows: 2017, 63/70; 2018, 42/55; 2019, 29/40. These ratings were particularly high and ranked in the top few topics covered in the whole workshop programme for every year of the STEM workshops.

The conveners of the workshop also conveyed to the authors that the students were very happy with the mathematics part of the workshop and that their understanding and confidence in mathematics and STEM as a whole had grown as a result of the whole workshop programme. The results are particularly encouraging given that students will see, learn and even embrace very new ideas and concepts in learning mathematics and as such can find mathematics and even the mathematics component of STEM an exacting and even challenging experience at times. We note, however, that students can find mathematics challenging and even confronting due to a number of different reasons beyond learning new concepts as outlined in this work.

To discover how the perceived increase in understanding differed between the curriculum and motivational topics, in 2018 and 2019 the students were further asked

Table 7.1 Student ratings of whether and how their overall understanding of the mathematics taught in the whole workshop had changed for the three years 2017, 2018 and 2019. The ratings were for a five-point Likert scale: 1 decreased a lot; 2 decreased; 3 stayed the same; 4 increased; 5 increased a lot

2017	2018	2019
100% increased or increased a lot	82% increased or increased a lot, the rest stayed the same	88% increased or increased a lot, the rest stayed the same

Table 7.2 Students were asked to rate whether and how their understanding of the Algebra or Calculus (curriculum) and Coding or Polytope (motivational) topics taught in the workshop had changed. The ratings were on a five-point Likert scale as in Table 7.1

	2018	2019
Curriculum Topics Algebra or Calculus	73% increased or increased a lot, the rest stayed the same	78% increased or increased a lot, the rest stayed the same
Motivational Topics Coding or Polytope	91% increased or increased a lot, the rest stayed the same	100% increased or increased a lot, the rest stayed the same

to rate how their understanding had changed in the curriculum and motivational topics separately. This was to discover whether and how the students' perceived increase in understanding differed between the curriculum topics and motivational topics (Table 7.2). Across the three years, the understanding in mathematics generally stayed the same or increased, with the majority rating their understanding as having increased in some manner. In comparing curriculum with motivational topics (across 2018 and 2019) we see that the perceived understanding in motivational topics increased slightly more.

The students were also given the opportunity to offer open-ended comments. Generally, the students wanted more time in the sessions, in particular the motivational activities. They also highlighted the usefulness and value of the curriculum topics. On the other hand (in 2018 and 2019), while they thought motivational topics were interesting and engaging, they were less certain about their value or usefulness for their future.

Finally, while the students enjoyed and gave positive feedback for all the sessions, it is worth noting that the reasons for the students' enjoyment of the curriculum topics may differ from the motivational topics. For the curriculum stream the students highlighted value and usefulness, while for the motivational stream the students highlighted engagement and interest.

Embedding Cultural Competence More Widely

The MLC has supported a culturally diverse student cohort from its inception including the support of Indigenous students. The MLC was established in 1984 (the first such initiative in Australia) and from its outset has supported students of educationally, socioeconomically and culturally diverse backgrounds. As described earlier in the chapter, the environment of the MLC has provided and continues to provide ample opportunity for students to develop and grow in cultural competence.

The STEM workshops have contributed to further embedding cultural competence across several dimensions. The first is the impact on the student participants, many of whom have continued to higher education in STEM degrees with some enrolling in the FEIT at the University. The post surveys revealed a strong motivation to engage and embrace STEM subjects. In addition to the recorded uptake of further STEM study, we regard the growth in the students' confidence and curiosity in exploring STEM as part of their lives as one aspect of their growth in cultural competence.

Related to this is the impact on and personal growth of the teachers involved. The experience of facilitating the workshop has contributed to a widening of the perspectives of the teachers and a deep appreciation of the individual perspectives as well as the capacity and potential of the students. For example, one of the teachers commented, 'I was surprised how quickly the students knew each other, formed subgroups and how quickly the class warmed up as the workshops went on'. Perhaps this positive theme to the workshop may be appreciated in light of the observation from Boon and Lewthwaite (2015, p. 456, paraphrasing Duchesne et al., 2015) that Aboriginal cultures 'emphasise relationship over task and cooperation over competition with a preference for cooperative and collaborative learning models in classrooms'.

Another dimension includes further initiatives for Indigenous students at the UoS. The contribution of the nominees to workshops has been highly regarded by the FEIT and the mathematics component has grown with each workshop. In addition, the MLC has continued to support Indigenous students in their STEM studies at the University, some of whom may have been past STEM workshop participants.

Furthermore, Dr. Phillips attended a NCCC Cultural Competence Leadership Programme, and is also now a panel member for the development of the University of Sydney's *Indigenous Strategy and Services* foundation year for Aboriginal and Torres Strait Islander students, in particular the STEM component. The experiences gained from the STEM workshops can be invaluable for all such initiatives.

Fourthly, the dissemination of the results and experiences more widely at conferences and in publications can contribute to the embedding of cultural competence more broadly. For instance, the evaluation methods employed the concepts of knowing and responding as well as the desire to provide students with a genuine voice. If adopted, these methods can serve to provide avenues and environments where cultural competence and, perhaps, cultural plasticity can grow and develop.

Conclusions

Learning mathematics can present more of a challenge than any other subject, because the ideas and concepts can seem, at least at first, more different than any other form of thinking. In order to learn new mathematical concepts, we need to expand our worldview to understand, encapsulate, incorporate and even adopt these ideas into our cultural perspective. However, all new ideas will be understood through our own perspective and perhaps draw upon our own cultural competencies. To abstract these new ideas and concepts to larger overarching mathematical concepts will require us to enter further into the mathematical realm where we may be able to draw less and less on our cultural references for help.

Furthermore, culture plays a deeper and often unrecognised role in our learning. The manner in which a subject is taught is often exclusively from the cultural perspective of the teachers and course designers. Giving students mathematics texts, presenting the mathematics in a pre-determined format, requiring the students then to answer specific exam questions about the material in a fixed time and environment, grading the responses, and classifying all of the dimensions of understanding using a single metric, is the product of a particular worldview. This perspective can have the effect of disenfranchising students from different backgrounds. We should acknowledge the culture that is embedded in an educational system and even a subject. Acknowledging the important part that worldview, perspective, resilience, culture and cultural competence play in the learning process can allow us to use cultural competence to enhance and improve understanding.

In this chapter we suggest that to learn new ideas (in mathematics), students are asked to grow and even adopt new cultural perspectives. In this sense, students are asked to go beyond acknowledging that there are alternate worldviews, but to understand and even adopt some of these ideas and extend their culture in the process. To do so requires not only cultural competence, but a form of cultural growth and plasticity. We further suggest that, as our experience with the MLC and the STEM workshops has shown us, it can be productive if we as teachers are equally as receptive to adopting some of the students' (cultural) perspectives. This is at least consistent with our expectations that students understand our ideas, concepts, perspectives and indeed culture. We are not suggesting that this is always possible to achieve, but the willingness to try can itself open up new perspectives and new ways of working and learning together.

At the MLC and the workshops, we have sought to cultivate this sense of cultural plasticity through attempting to know and respond to student needs continuously and in ways that are appropriate for each individual.

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Appendix 1

See Fig. 7.1.

Appendix 2

The teachers of the workshops responded to the students valued and continual feedback by dedicating much time and effort to improving details. Examples of this can

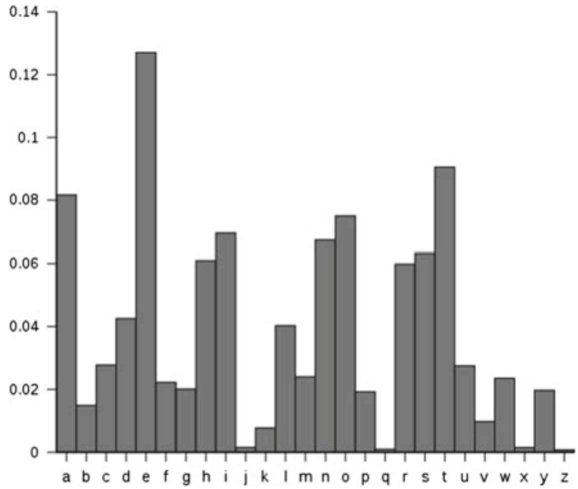

Fig. 7.1 Representation of a frequency distribution of letters in 'standard English'. Distributed to motivate ideas of how to crack a 1-key Vigenére Cipher and to promote thought about how to use multiple shifts to make a Vigenére Cipher more difficult to crack

be found in the continual improvement of the questions asked in the cryptography session of the workshops as shown in Fig. 7.2.

As an example, to make the process of cracking a 2-key Vigenère code less time-consuming, so that more emphasis could be placed on the code cracking process and less on the mechanics, Question 2 was progressively improved as follows:

- The letters in the code were coloured to simplify the process of picking out which parts of the code should be shifted by different amounts.
- Different groups were tasked with, focussing on either the odd or even letters and collaborating with other groups once they had decrypted their subset in order to recover the entire message.

Vigenère Ciphers Tuesday 9th of July 2019

1. Make up a short message. Then by shifting each letter in the message by 4 letters encode your message. Then pass the code to a second group to decode. Maximum length is one sentence. The 1-letter key for this shift is ...
2. The following has been enciphered using a 2-letter key. See if you can find the key and decode the message!

Hint: It is a weather forecast.

```
WIAKOGMWNQUBOMTWYVPVNUHQUTFQUBOMDMZBSQNPAEPV
KAIMJWTQUOUWYBOMYTFNPNAMLVAWLQNPAMLVRQSWTMAZ
LAWMYPVCYQUBOMTQKLSMVNAPLLHGAPLVIMJWTQUOSQNP
AQUBOMLDLVPVNYBMZBPWUBOZLMLVJZFXAQVVRMFQZUSK
```

Fig. 7.2 First (of three) pages of the Vigenère Cipher project sheets. The second question gives the first code that needs 'cracking'

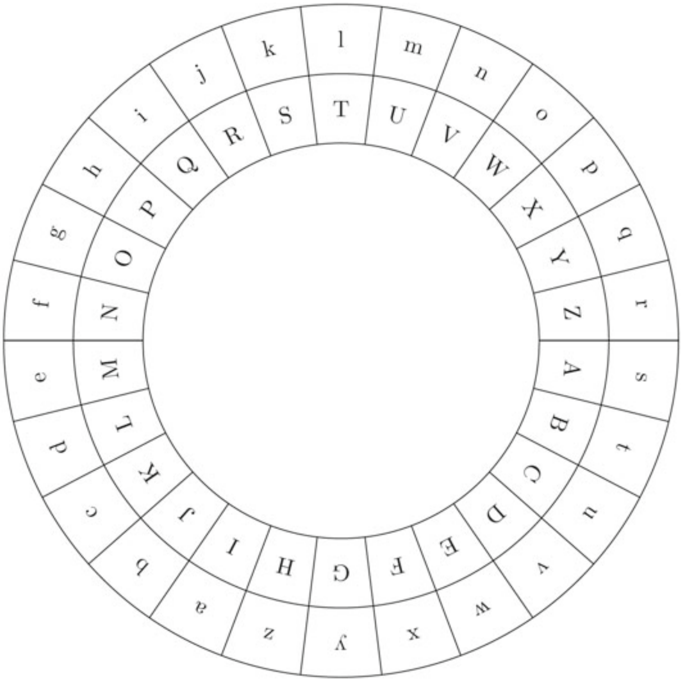

Fig. 7.3 Representation of an Alphabet Wheel. This graphic was distributed to the students to assist with cracking the code in the question. The shift in the illustration is 8, which is used for the even letters in Question 2 (of Fig. 7.2)

- The message was specifically designed and modified so that the most common letter in each subset (odd or even) was e, ensuring that it is simpler to guess the correct shift in the first instance.
- Alphabet wheels were given to the students, as shown in Fig. 7.3 to reduce the time spent on the mechanistic aspects of shifting the (sections) of the code.
- The value of these and other improvements, which are somewhat hidden in subsequent workshops, becomes apparent as the students managed to cooperate and use their various cracked section to reconstruct the hidden message, as well as enthusiastically crack quite complex codes, in their own time.

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