# Pre-Service Teachers' Conceptual Confidence in Mathematics and Science: Initial Tool Development

Kate Quane
*Adelaide University*
Kate.Quane@adelaide.edu.au

Rosalie Miller
*Flinders University*
Rosalie.miller@flinders.edu.au

Sarah Wickham
*Flinders University*
Sarah.wickham@flinders.edu.au

Timna Garnett
*Flinders University*
Timna.garnett@flinders.edu.au

Shaileigh Rowtcliff
*Flinders University*
Shaileigh.rowtcliff@flinders.edu.au

Leanne Larkin
*Adelaide University*
Leanne.larkin@adelaide.edu.au

Helen Booth
*Adelaide University*
Helen.booth@adelaide.edu.au

Teacher education programs have a responsibility to develop teachers' confidence as teachers in both mathematics and science, reducing the barriers known to affect the efficacy of teaching of these curriculum areas in the primary classroom. However, Pre-Service Teacher (PSTs) often lack the confidence in teaching mathematics and science. We propose an initial tool using the Cartesian Plane to assess PSTs confidence with specific concepts and how to teach these concepts in mathematics and science. We anticipate that the tool will inform teacher education programs, pedagogical practices and have further implication in the teaching of mathematics and science.

## Introduction

Mathematics is a high-status discipline and success in the mathematics strongly correlates with future economic success (Ernest, 2018). Many people, including many primary Pre-Service Teacher (PSTs), have negative learning experiences, shaped by personal experiences and exposure to social images of mathematics (Ernest, 2018). This can result in attitudes towards mathematics that include low levels of confidence and mathematics anxiety (Ernest, 2018). There are also calls to improve the quality of science instruction in classrooms across the globe (Naidoo & Naidoo, 2023) with specific concerns about teachers in primary/elementary years (F-6) due to the lack of core content knowledge training in teacher education courses. These concerns include low levels of science teaching confidence, which may stem from a lack of interest in science, science anxiety, and/or experiences of effective science teaching, science identity (Menon & Sadler, 2016; Naidoo & Naidoo, 2023). Limited scientific content knowledge, combined with the responsibility for teaching multiple strands, poses challenges for preparing teachers for classroom realities.

Furthermore, practicing and pre-service teachers may be unaware of gaps in their own content knowledge. As Brodie and Sanni (2014) argue, content knowledge is foundational to pedagogical content knowledge. However, as Shulman (1986) cautions, "assumptions of ignorance" have led to an overreliance on formal assessment of what teachers do not know (p.1).

If primary PSTs retain these negative attitudes and a lack of confidence with concepts as they move forward into their teaching career, it is likely to impact their mathematics and science teaching practice, and through their teaching practice, impact the attitudes and images of

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mathematics and science carried by their future students. Teacher education programs have a great opportunity and responsibility to develop teachers' confidence. As teacher educators with a focus on both mathematics and science, we aim to reduce the barriers known to affect the quality teaching of these curriculum areas.

## Literature Review

This literature review draws together three interconnected areas of research that inform the focus and design of this study. First, literature examining PSTs' diversity and the ways in which they navigate, resist or conform to expected norms provides a lens for understanding how confidence and identity are shaped in teacher education contexts. Second, research on teachers' and PSTs' confidence in mathematics and science highlights the affective dimensions of learning. Finally, an examination of how common metaphors and the connotations associated with these metaphors are used to capture teachers' confidence.

### Pre-service teachers' diversity and conforming to expected norms

Hilton and Saunders (2024) note the expansion of definitions of diversity, and we follow their definition, considering diversity to include "difference in sex and gender; disability; beliefs and religion; social classes and socio-economic status; as well as race, ethnicity and culture" (p. 1066). Included under the umbrella of disability is neurodiversity/neurodivergence. PST diversity is integral to understanding confidence in mathematics and science as success in education must not be viewed as individual in nature. Ernest (2018) highlights the role of cultural capital in mathematics achievement, with implications for mathematical confidence. Education, including mathematics and science education is structured by dominant norms of saying, doing and relating (Grootenboer & Edwards-Groves, 2019). These norms privilege standardised, seemingly neutral forms of knowledge and often positioning alternative ways of thinking and knowing as irrelevant or inferior (Louie et al., 2021). Such dynamics contribute to persistent imbalances in achievement and confidence between dominant and marginalised groups (O'Keeffe & Paige, 2021). In science, PST diversity encompasses variation in cultural and religious beliefs, which can influence confidence in teaching topics perceived as controversial (Mavuru & Pila, 2021). In addition, PSTs also bring their history of science learning with them into their Initial Teacher Education (ITE) program, with PSTs often identifying teaching practices in high school and university as a contributing factor to their confidence in teaching science to their learners (Mavuru & Pila, 2021). PSTs may also bring preconceived stereotypes about students and schooling contexts into the classroom, highlighting the complex interplay between identity, confidence and diversity in teacher education (Chen & Mensah, 2018).

### Primary teacher and preservice teachers' confidence in mathematics and science

This study is focused on primary undergraduate and postgraduate PSTs who are generalists, with the majority teaching across most learning areas. This contrasts with secondary PSTs, who have chosen specialisations. This means that the majority of primary PSTs will be required to teach mathematics and science, whereas there is a greater possibility that the secondary PSTs who will teach mathematics and science have chosen to specialise in these areas, meaning they are more likely to have a greater interest and confidence in the concepts within their chosen specialisation. The prevalence of anxiety towards mathematics and mathematics teaching experienced by primary PSTs is a significant factor that impacts their future teaching of mathematics (Grootenboer, 2008; Larkin, 2016). Menon and Sadler (2016) find there is a similar issue with primary pre-service teachers within the science learning area, additionally noting a possible correlation between PSTs' science content knowledge and science teaching self-confidence.

Confidence is a term that is commonly used within research studies but often not defined. Confidence connects to an individual's belief in their own competence to undertake a task successfully (Lau, 2022). Teacher confidence or anxiety is a key factor in the development of effective mathematics pedagogical knowledge by PSTs (Larkin, 2016). However, Larkin (2016) notes that the increase in asynchronous learning experiences, with the rise in online learning options within the Initial Teacher Education setting, creates a challenge in developing PST confidence with and understanding of mathematical content. This is because of the challenge of retaining the dynamic interaction between learners and educators in an asynchronous teaching model (Kim, 2011).

Teacher's lack of confidence in the subjects that they teach can negatively affect students' engagement, achievement and interest in the subject (Setlatentoa, 2018). Most PSTs identify as "non-science" people, reporting negative school experiences and poor attitudes towards the subject and the capacity to effectively teach science (Mulholland & Wallace, 2002). Whilst PSTs may feel confident in teaching some science topics, they report lower confidence in other topics (Mavuru & Pila, 2021). PSTs level of confidence reduced in meaningful engagement with the content, particularly abstract concepts that are difficult to represent concretely for learners (Mavuru & Pila, 2021).

## Metaphorically speaking: Examining common visual metaphors in education.

In an attempt to develop a tool to ascertain pre-service teachers' confidence levels in mathematics, we explore different analogies associated with mathematics. Initially, the learning pit came to mind. In this metaphor, a learner is depicted descending into a "pit" of confusion or uncertainty, working through struggle before ascending the other side and thereby reaching new heights in understanding. We could see links between the learning pit and what pre-service teachers experience when they are engaging in mathematics curriculum courses at the tertiary level and the prospect of teaching mathematics. That is experiencing uncertainty before experience success. In discussing this metaphor as a research team, there was great discussion about the usefulness and the underlying meaning of the metaphor. This led to considering the metaphor of inverting the pit into a mountain. Both metaphors have been extensively used in education to depict the learning process. However, when critically examining these metaphors, we realised that while there are positive associations with both, there are also negative connotations.

James Nottingham conceptualised the Learning Pit™ in the mid-2000s as a metaphorical tool to introduce cognitive discomfort and productive struggle that can occur when learners grapple with challenging concepts. Drawing on constructivist traditions, Nottingham framed the pit as a visual heuristic to help students recognise the value of uncertainty, confusion, and the eventual emergence of insight. Since its introduction, the Learning Pit™ has been widely adopted in schools, professional learning programs, and growth-mindset initiatives, partly due to its accessibility and resonance with Dweck's (2006) theorisation of challenge and persistence. Despite its widespread adoption, the Learning Pit™ metaphor carries several negative connotations that warrant careful consideration. By depicting learning as a descent into a 'pit', the model may evoke imagery of failure, entrapment, or deficit, potentially reinforcing anxiety rather than fostering resilience for some learners. The visual image of being *stuck* or *in a pit* can amplify feelings of helplessness, particularly for students with a history of low academic confidence or those who interpret struggle as a sign of inability rather than growth (Dweck, 2006). It can be argued that the metaphor implicitly individualises responsibility for progress, suggesting that escaping the pit depends primarily on personal effort. As such obscuring the role of instructional design, pedagogical approaches and systemic inequities that shape learners' experiences of difficulty (Wright et al., 2022). The linear upward trajectory depicted in many versions of the Learning Pit™ can also oversimplify the nonlinear and iterative nature of understanding, positioning successful learning as a singular moment of "climbing out" rather than an ongoing process that may involve repeated cycles of uncertainty (Abcouwer et al., 2016). Consequently, while the Learning Pit™ aims to normalise productive struggle, its metaphoric framing may unintentionally reinforce deficit perspectives and narrow conceptions of what meaningful learning entails.

In contrast, Boehm (1959) suggest that learning, and in particular, mathematics education, is like climbing a mountain. Boehm (1959) described mathematics as being for people "who like to climb intellectual mountains" (p. 7). While this metaphor has endured in mathematics education discourse, its implications also warrant further examination. The notion of mathematics as a mountain foregrounds challenge, perseverance, and the satisfaction of ascending the peak of the mountain. This imagery aligns with traditional narratives of rigour and intellectual conquest (Dweck, 2006; Gutiérrez et al., 2023). A contrasting examination of the imagery reveals the metaphor reinforcing elitist and exclusionary views of mathematics as a domain reserved for the exceptionally capable, able or determined (Boaler, 2015). The mountain metaphor may inadvertently position learners at the base of an intimidating ascent, leaving them feeling overwhelmed, unable to see a path forward, and overemphasising struggle. Research on student attitudes suggests that metaphors framing mathematics as inherently arduous can discourage participation and negatively shape self-concept, particularly among students who already feel marginalised in the discipline (Andersson et al., 2015; Erdogan & Yemenli, 2019; Gutiérrez et al., 2023; Larkin & Jorgensen, 2016). While evocative, the 'intellectual mountain' and Learning Pit™ analogies must be interrogated for the ways they shape expectations of difficulty, success, and who is perceived as belonging in mathematics.

This left us in a quandary in terms of developing a visual tool to ascertain pre-service teachers' confidence levels in mathematics and science education. So, perhaps not surprising, we explored how the Cartesian Plane can be used as a visual metaphor to document PST confidence with mathematical and science concepts. In doing so, developing a tool that can be used to answer the research question (RQ): *How do we capture PSTs' confidence in specific concepts as documented in the Australian Curriculum (F-6) mathematics and science?* Building on this RQ, we seek to answer the following: *How do we use PST's confidence data about specific concepts to inform the responsive teaching and learning of mathematics and science education?*

## Theoretical Framework

This study is situated at the intersection of sociocultural theories of education and affective theories of learning. Together, these perspectives frame PSTs confidence in mathematics and science not as an individual trait or deficit, but as a socially produced, culturally mediated, and historically situated phenomenon.

Sociocultural theories of learning foreground the idea that knowledge, identity, and confidence are constructed through participation in socially and culturally patterned practices (Grootenboer & Edwards-Groves, 2019). From this perspective, mathematics learning is not neutral or universal but is embedded within dominant cultural norms about what counts as legitimate mathematical knowledge, ways of knowing, and ways of being a 'successful' mathematics learner. Drawing on Bourdieu's notion of cultural capital, Ernest (2018) argues that school mathematics privileges the cultural resources, dispositions, and experiences of dominant groups. PSTs who do not possess or recognise these dominant forms of capital may experience mathematics and science as alienating, leading to lower confidence and a diminished sense of belonging in the discipline. Within this framework, PST confidence in mathematics and science is understood as relational rather than individual. That is, it emerges through alignment (or misalignment) between PSTs' identities, histories, and ways of knowing, and the norms embedded in mathematics education and ITE programs. Within this study, PST confidence is therefore conceptualised as a social justice issue, shaped by systemic structures, assessment practices, and discourses of ability that determine who is positioned as capable, legitimate, and confident in mathematics.

Affective theories of learning emphasise the role of emotions, beliefs, and self-perceptions in shaping engagement and achievement (Dweck, 2006). Ernest (2018) highlights how negative mathematical and science experiences often result in poor confidence, and anxiety, patterns that are particularly prevalent among primary PSTs. Importantly, these affective responses are not isolated psychological phenomena. Rather, they are deeply intertwined with learners' identities and prior experiences within institutional and cultural contexts. PSTs enter ITE programs carrying embodied histories of mathematics and science learning that influence how they interpret challenge, struggle, and success. This study positions PST confidence as both an outcome of past experiences and a mediating factor in future teaching practice, reinforcing the cyclical nature of affect, identity, and equity in mathematics education.

## Methodology

Metaphors are powerful cognitive and cultural tools that shape how individuals conceptualise abstract experiences such as learning (Lakoff, 1987). In education, metaphors such as the Learning Pit™ and mountain climbing are not merely illustrative but actively construct meanings about struggle, success, and belonging. In response to the limitations of dominant metaphors, this study explores the Cartesian plane as a representational tool for capturing PST confidence in mathematics and science. Unlike linear or hierarchical metaphors, the Cartesian plane allows for multidimensional, non-linear representations of confidence across mathematics and science concepts. This aligns with sociocultural and critical perspectives by resisting deficit framings and enabling PSTs to locate their confidence relationally rather than hierarchically. By positioning confidence as variable, contextual, and dynamic, the Cartesian plane offers a conceptual alternative that foregrounds diversity of experience and challenges narrow, standardised conceptions of mathematical competence.

The Cartesian Plane is used to map confidence levels (x axis) against levels of understanding for specific mathematics and science concepts (y axis) using a ten point scale. Costello et al. (1991) define a concept as "a group or set of items which all share a property" (p. 28). While the definition by Costello et al. is situated in mathematics education, we argue that the definition transcends into science education.

## Initial Findings: Tool Development

In pursuit of developing a tool to capture PSTs' confidence levels in understanding specific mathematics and science concepts were identified which is presented as initial findings in this paper. We acknowledge from the outset the considerable depth and breadth of possible concepts across both learning areas. To ensure the tool was both feasible and practical, the research team collaboratively identified core concepts for primary mathematics and science. The process was guided by the Australian Curriculum, drawing on the six mathematical strands and the four science understandings. Table 1 presents the initial concepts identified for mathematics and science. While these concepts are presented in list form for clarity, we acknowledge that such representation may imply discreteness. In practice, the concepts are interrelated. The identification of concepts was the first step to answer the RQ: *How do we capture PSTs' confidence in specific concepts as documented in the Australian Curriculum (F-6) mathematics and science?*

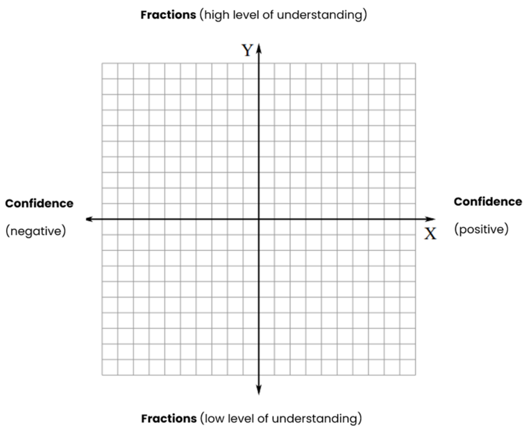
**Table 1:**
*Initial concept identification for mathematics and science*

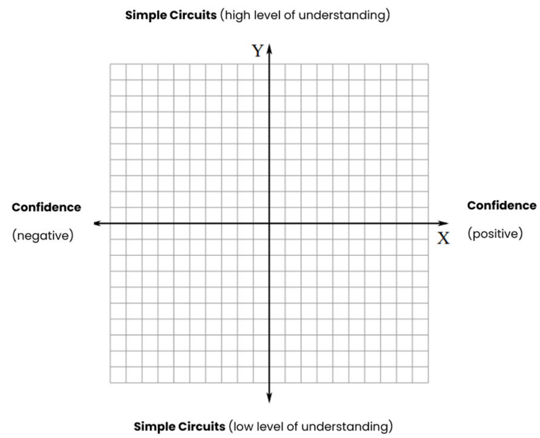
| **Mathematics** | **Science** |
|---|---|
| Number | Physical Science |
| • Place Value | • Movement/push pull energy |
| • Fractions, decimals, percentages | • Force – gravitational, friction and magnetism |
| • Multiplication and Division | • Light and colour (and shadows) |
| • Addition and Subtraction | • Simple circuits |
| Algebra | • Renewable energy |
| • Repeated patterns | • Energy transformation |
| • Additive patterns | Earth and Space Sciences |
| • Growing patterns | • Solar system – day/night/seasons |
| • Unknowns in number sentences | • Movement of earth and other planets |
| • Equality/balance/equivalence | • Rocks/soils/mud/minerals |
| • Expressions and Equations | • Water cycle |
| • Order of operations | • Weathering |
| Measurement | Biological Science |
| • Informal units of measurement | • Plants and Animals |
| • Formal units of measurement | • Form and features of Living things/Non-living things |
| • Attributes to be measured (Length, Area, Volume, Capacity, Time) | • Life cycles, Habitats and Food chains |
| Space (Geometry) | • Survival and Adaptations |
| • 2D shape | • Ecosystems |
| • 3D solids | Chemical Science |
| • Cartesian Plane | • Mixing/mixtures |
| • Location and mapping | • States of matter/solid, liquid, gas |
| • Transformation (reflection, rotation, translation, enlargement) | • Properties of Materials |
| Statistics | |
| • Data collection | |
| • Data Representation | |
| • Data analysis | |
| Probability | |
| • Likelihood | |
| • Comparison | |
| • Prediction simulations or models | |
| • Probability events and outcomes | |

In analysing existing visual metaphors of learning, we identified that visual metaphors of the learning pit and mountain are unidimensional and do not provide scope for mapping the intersection between conceptual knowledge and confidence. The Cartesian Plane will act as a visual metaphor whereby PST will map their confidence levels with their level of understanding for each of the concepts shown in Table. It is intended that PSTs will mark on the Cartesian plane a single co-ordinate indicating their confidence for each concept. The data can be used to ascertain relatively quickly both an individual and a group of PSTs' confidence levels. For example, a coordinate placed in quadrant 1 indicates that a PST is confident in and has a high level of understanding in a particular concept. Cartesian planes for each PST will then be combined into a single visual representation, providing an indication of their confidence levels for both mathematics and science. The combined representations acting as a bidimensional visual metaphor of PST's confidence and understanding. It is also intended that results from a cohort of PSTs will be combined into a single plane mapping a group of PSTs' confidence levels with a given concept. Doing this provides a way of determining a group of PSTs' confidence levels at the beginning of a workshop allowing for responsive teaching practices by teacher educators. Figures 1 and 2 show items for mapping PSTs confidence levels in fractions and simple circuits.

**Figures 1 and 2:**

*Sample Cartesian model for mapping PSTs confidence levels in mathematics and science concepts*




Please explain why you place yourself in this quadrant.

Please explain why you place yourself in this quadrant.

An additional section of the tool will capture PSTs' demographic information with questions in this section ascertaining PSTs' i) Schooling experience in mathematics and science; ii) Tertiary education (undergraduate or postgraduate); iii) Work related experience (student support work, tutor, other); iv) Success and challenges in mathematics and science; v) Daily experiences in mathematics and science; vi) Family, peer, personal and social messages and images of mathematics and science. This section brings together PSTs confidence with their social capital and diverse backgrounds. Combined, the Cartesian Plane data and PST background information will provide a holistic picture of the complexities of PSTs' confidence in mathematics and science.

## Implications and Conclusion

We anticipate the proposed model to be an innovative approach to capture PSTs confidence in specific mathematics and science concepts. In using the Cartesian Plane, we aim to gather data pre and post workshop to be able to track PST confidence levels. The collection of this data will assist in the identification of areas of strength and challenge with the PSTs' confidence in their knowledge of content and teaching within primary mathematics and science. This has implications for the PSTs undertaking mathematics and science courses to develop their self-awareness and confidence in their own conceptual understanding and in doing so has the potential to strengthen their knowledge. By collecting this data during workshops, it will support teacher educators to enact responsive teaching practices and thereby considering the diverse backgrounds of PSTs. The collection tool is visual and quick to interpret, allowing for modifications to short- and long-term planning to be made as part of a responsive teaching approach.

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