The importance of developing a metric to classify student experience in mathematics within the framework of intensive block teaching

Calum Downie[abc], Rudi Klein[ab] and Puspha Sinnayah[ab]

Corresponding author: Puspha Sinnayah, (puspha.sinnayah@vu.edu.au)
[a] First Year College, Victoria University, PO Box 14428, Melbourne VIC 8001, Australia
[b] Institute for Health and Sport, Victoria University, Melbourne, VIC 8001, Australia
[c] Torrens University, Melbourne, VIC 3000, Australia

Abstract

The number of students enrolling in higher level mathematics units at high school have been in decline for a number of years. This is of particular concern when they then continue their studies within undergraduate STEM disciplines at University, leading academics to search for better methods to support mathematical instruction. The aim of this study was to investigate the development of a simple and robust tool to classify students' mathematical capacity within a time compressed block teaching environment. One hundred and seventy-six first year students completed a survey reflecting on their level of comfort, competence, and enjoyment of mathematics, including their highest level of previous study in the discipline. Students also completed a short quiz to establish a pre-learning numeracy skill baseline. The survey provided data for development of the metric, from which, three groups ranked on their mathematical ability (low, medium and high) were identified which were then matched with scores arising from their baseline assessment. The classification grouping was uniform across all four offerings of the mathematics unit taught and matched with common baseline assessment scores. The importance of this tool shows both reliability and robustness in being able to identify students likely to have difficulty in studying undergraduate mathematics especially within the context of the time limited intensive block teaching, permitting early intervention to help students at risk of failure to succeed.

Keywords: mathematics, self-efficacy, pedagogy, active learning technology, block teaching model

Introduction

Enrolment in secondary school science and mathematics subjects has been declining for some time. This decrease is particularly evident in the final years of secondary education (Di Martino & Gregorio, 2019; Kennedy, Lyons, & Quinn, 2014; Timms, Moyle, Weldon, & Mitchell, 2018; Weink, 2015), and occurs in parallel with the delivery of advanced mathematics (Budgen & West, 2018; Kennedy et al., 2014). This decreasing enrolment trend in science, technology, engineering and mathematics (STEM) at the secondary level are by no means restricted to Australia, reports from the UK and Europe, the Middle East and Asia all echoing the same decline (Kennedy et al., 2014). The educational challenge arising from such a decay, while notable in the high school context, has profound follow-on effects within the higher education sector (MacGillivray, 2009). In addition, this can be more obvious within units that are taught in the block model time frame as there is less time to reflect on the performance of individual students.

Lack of mathematical learning at the end of secondary education has, in the tertiary sector, resulted in a broad belief that there is a lack of numerical competence in undergraduates, particularly in the first year of their study (Boyd, Cullen, Bass, Pittman, & Regan, 1998). The lack of advanced mathematical learning before entering University, in particular, has resulted in students who are ill-prepared for the rigours of higher education STEM learning (Faulkner, Hannigan, & Fitzmaurice, 2014). This is of particular concern as, while there is a reduction in advanced mathematics enrolment in secondary school, there is an increased enrolment seen in higher education science programs (Wilson & Mack, 2017). The difficulty in this nexus of reduced learning of secondary STEM subjects and increased tertiary application/enrolment is the need to simultaneously address the knowledge gap and enable mastery of mathematics in higher education. An important consideration for the academic is how to address the needs of a large cohort of students who present with a wide array of both confidence and ability in mathematics within the block model setting. This is particularly evident in sciences where a broad range of student numeracy has been observed, perhaps arising from the noted variability in the level of mathematics studied at secondary school (Green et al., 2017) where it has been observed that as much as 45% of recent secondary school leavers had not attempted a higher level of mathematics (Wilson, 2013).

The challenge surrounding this lack of mathematical exposure cannot be overstated, particularly in the context of a student cohort who are academically disadvantaged (Winchester, Klein, & Sinnayah, 2021) and often experience low numeracy (Downie, Klein, & Sinnayah, 2019). This is particularly evident at Victoria University, which has a high population of disadvantaged students (Chapin & Oraison, 2019; McCluskey, Weldon, & Smallridge, 2019; Messinis & Sheehan, 2015) now studying under the recently adopted Victoria University Block Model (VUBM) curriculum. The idea behind the introduction of the VUBM was to better support this cohort of the student population from the outset (Winchester, Klein, & Sinnayah, 2021). Victoria University adopted the VUBM (McCluskey et al., 2019) which combines intensive teaching and curriculum designed to aid transition in first year of tertiary study. In this model, students complete a single unit of study over a four-week period before moving on to the next, thus there are multiple potential offerings of a unit within an academic year. Unit of study is a term used within the Australian Higher Education sector, equating to a course in North America, module in The United Kingdom or subject in New Zealand contexts (McCluskey et al., 2019).

Successful learning of Mathematics is influenced by both intrinsic competence as well as student self-perception of ability (Calvert, 1981; Tariq & Durrani, 2013). Students who have completed a general level of mathematics, or who have only ever achieved lower grades, are likely to exhibit greater anxiety towards studying the discipline (Rozgonjuk et al 2020; Daker et al 2020), and there is no literature relating this to the block teaching method. It has therefore been recognised that the effective teaching of mathematics should include a multi-dimensional approach, considering the students: emotional response to the unit, conception of their abilities in the unit, and behaviour towards the unit (Hart, 1989). Within the broad umbrella of science, there is noted anxiety in many students when confronted with scientific content (Daker et al, 2021). This would appear as a result of poor secondary experience of science through deleterious learning, messaging or inadequately prepared teaching staff, along with the gender bias in sciences and belief that science is boring (Buckley, Reid, Goos, Lipp, & Thomson, 2016; Crane & Cox, 2013; Ingvarson et al., 2014). Compounding the potential of anxiety with respect to their STEM learning is the students' self-efficacy within the discipline. An individual's disbelief in their ability to master a skill can subvert any attempts at future mastery (Bandura, 1977; Pajares, 1996; Walker, 2010), and is built upon a number of factors including historical performance and emotional arousal (Crane & Cox, 2013). In essence it boils down to, "Do I believe I can I do it?", "Am I good at it?" and "Do I enjoy it?".

In practice, understanding student self-efficacy and historical performance should provide the teaching academic with an understanding of the students' capacity for success in the discipline. However, as yet, there is no concise method or approach by which this might be achieved. The aim of this study, therefore, is to describe the development of an easily deployed assessment tool, which is able to measure the students' capacity to improve their mathematical skills within the block teaching model.

Methods

Ethics
This study was approved by the Ethics Committee at Victoria University (HRE-17-192). Informed consent was obtained from all students and participation proceeded on a voluntary basis only.

Participants
One hundred and seventy-six first-year students enrolled in the "Mathematics and statistics for Biomedicine" (HHH1001) unit within a Bachelor of Biomedical Science degree, across four independent deliveries in 2019 and 2020, participated in this study. All students completed a pre-unit maths assessment to determine the baseline mathematical capability of the cohort.

The questionnaire and development of the metric
An anonymous option-based questionnaire was conducted prior to commencing the unit to determine their self-efficacy of, and previous studies in, mathematics. Contained within the questionnaire, the following three questions were of particular importance for the development of the metric reflecting the work by Hart (1989); "how confident you are with maths skills? how competent are your maths skills? and, do you enjoy maths?". Student responses were collected from four independently taught unit deliveries in 2019 and 2020 and measured via a 10-point Likert-type scale (1 being not at all and 10 being absolutely), with the data entered into the following equation;

$$Discipline\ Capacity = \\ (Current\ Confidence + Current\ Competence + Current\ Enjoyment) \\ * Highest\ Level\ of\ Mathematics\ Education$$

The maximum Discipline Capacity (DC) score was calculated by adding the levels of self-assessed confidence, competence and enjoyment than multiplying these by the factor of highest level of mathematics education previously obtained or studied (1 for elementary, 2 for intermediate and 3 advanced). Elementary mathematics is that level commonly taught in primary and secondary education including concepts such as basic algebra, geometry and number theory. Intermediate level mathematics extends such learning in areas such as algebra and pre-calculus. Advanced level mathematics involves complex learning such as calculus, statistics and probability. The aim being to incorporate the influence of previous education as this, despite the bias of the self-assessment of the student, may impact on their mathematical capacity. The maximum DC score from this formula, therefore, was 90. First and third quartile ranges were determined within the cohorts DC scores, allowing for the identification of three groupings of comfort in mathematics: low (<= 17), medium (18-43), and high (=> 44).

Mathematics assessment

The mathematics assessment consisted of a short, 10-question short-answer quiz composed of three subject areas: algebra, trigonometry and ratios, and percentages and averages. The basis for each section was built on the learning outcomes from Year 10 (elementary secondary school) level mathematics.

Data analyses

To determine the distribution profile of students across the three groupings, a frequency analysis was conducted. Following this, 1st and 3rd quartile ranges were determined based on the DC score. An ANOVA was then conducted to determine the effect across these groups on the pre-unit DC scores and maths quiz results. All statistical analyses were performed using SPSS (v.26, IBM, USA) with the level of significance set at $p < 0.05$.

Results

Discipline capacity scoring and grouping

DC scores between groups, and by offering, are shown in Table 1. There were no differences in low and medium DC groups across the four offerings in the unit. In the high DC group, there was a significant difference in capacity scores between the first and third unit offerings (59.43 ± 11.84 compared with 49.23 ± 6.80, p = 0.01).

Table 1. Discipline capacity scores by group and unit offering

	Offering 1 (n = 54)	**Offering 2 (n = 30)**	**Offering 3 (n = 74)**	**Offering 4 (n = 18)**	***p***					
					1v2	**1v3**	**1v4**	**2v3**	**2v4**	**3v4**
Low DC	8.33 ± 5.30	12.39 ± 3.56	14.11 ± 3.20	16.88 ± 2.75	0.98	0.74	0.46	1.00	0.98	1.00
Medium DC	27.75 ± 8.05	29.38 ± 7.96	32.00 ± 8.14	31.50 ± 8.85	1.00	0.64	1.00	1.00	1.00	1.00
High DC	59.43 ± 11.84	59.75 ± 15.11	49.23 ± 6.80	56.00 ± 16.97	1.00	***0.01*** *****	1.00	0.40	1.00	0.80

DC = Discipline Capacity, maximum capacity score = 90, **** significance at p = 0.05***

Figure 1 shows distribution of DC score by group, and by offering number. In all offerings, the medians of the low-capacity group are uniformly lower than that of the medium group. Similarly, the medians of the medium capacity group are lower than that of the high group. While outliers are present in the low and high-capacity groups, there are no interactions with other groups.

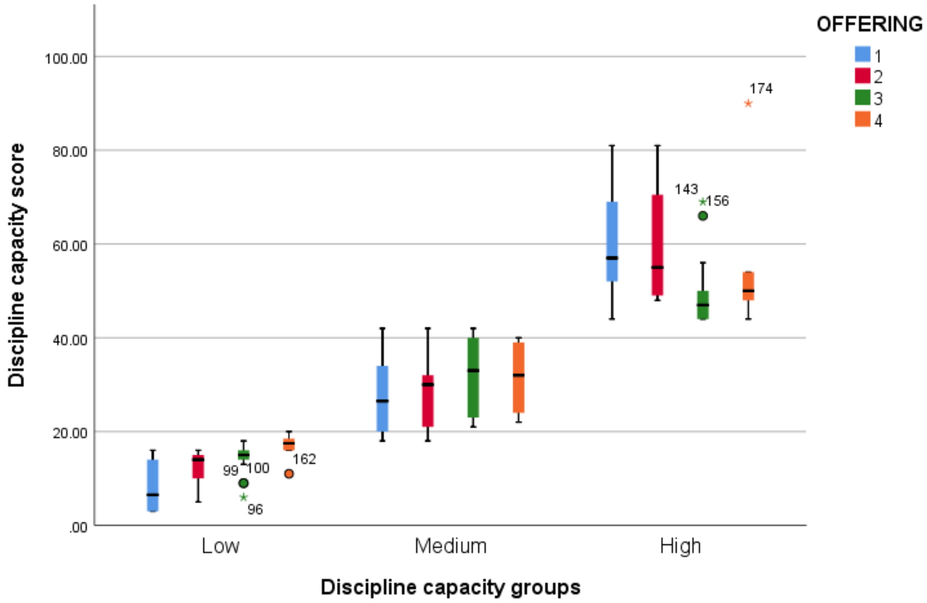

Figure 1 ***Distribution of discipline capacity scores, by group (Low, Medium and High) and offering***

Metric grouping

Discipline capacity grouping

Distribution of students across DC groups is shown in Table 2. In offerings one and three there were comparatively even distributions between the low and high groups, both of which were less than that of the medium group. This distribution is not seen in offerings two and four.

Table 2. Distribution of students by DC group, by unit Offering, and Overall

	Offering 1 (n = 54)	**Offering 2 (n = 30)**	**Offering 3 (n = 74)**	**Offering 4 (n = 18)**	**Overall (n = 176)**
Low DC	n = 12	n = 13	n = 18	n = 8	n = 51
Medium DC	n = 28	n = 13	n = 34	n = 4	n = 79
High DC	n= 14	n = 4	n = 22	n = 6	n = 46

DC = Discipline Capacity

Previous mathematical studies, by classification group

The previous level of mathematics attained for each student by DC group, by offering and overall is shown in Table 3. Elementary level mathematics was reported most commonly in the low DC group (82.3% overall) while forming approximately one third of reports in the medium DC group (30.4%). This level of mathematics was not reported in the high DC group. Intermediate level mathematics was most commonly reported in the medium and high DC groups (68.4% and 69.6% respectively) with a minority in the low DC group (15.7%). Finally advanced level mathematics was commonly reported in the high DC group only (30.4%), with only single students in each of the low and medium DC groups reporting this level of mathematical attainment (2.0% and 1.2% respectively).

Table 3. Previous mathematical studies by DC group, unit offering and overall shown as % of total

		Offering 1 n (%)	Offering 2 n (%)	Offering 3 n (%)	Offering 4 n (%)	Overall n (%)
Low DC n = 51	Elementary	9 (75.0)	11 (84.6)	17 (94.4)	5 (62.5)	42 (82.3)
	Intermediate	2 (16.7)	2 (15.4)	1 (5.6)	3 (37.5)	8 (15.7)
	Advanced	1 (8.3)	0 (0)	0 (0)	0 (0)	1 (2.0)
Medium DC n = 79	Elementary	9 (32.1)	4 (30.7)	9 (26.5)	2 (50)	24 (30.4)
	Intermediate	19 (67.9)	9 (69.3)	24 (70.6)	2 (50)	54 (68.4)
	Advanced	0 (0)	0 (0)	1 (2.9)	0 (0)	1 (1.2)
High DC n = 46	Elementary	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
	Intermediate	5 (35.7)	2 (50)	20 (90.9)	5 (83.3)	32 (69.6)
	Advanced	9 (64.3)	2 (50)	2 (9.1)	1 (16.7)	14 (30.4)

DC = Discipline Capacity

Student self-reflection, by classification group

Student self-reflection scores are shown in Table 4. In the low DC group, there were no differences in scoring of self-perceived confidence (Con), competence (Com) nor enjoyment (Enj) between the four separate unit offerings. Exceptions to this observation include between confidence in offerings one and three (offering one significantly lower, p < .01), competence in offerings one, three (offering one significantly lower, p < .01) and four (offering one significantly lower, p = .01), and enjoyment in offerings one, two and four (p < .01). In the medium DC group, there were no differences other than significantly lower enjoyment in offering one when compared to offering four (p = .04). There were no differences in any variable, in any offering, for the high DC group.

Table 4. Student self-reflection scores, by DC group and offering

		Offering 1 Mean ± SD	Offering 2 Mean ± SD	Offering 3 Mean ± SD	Offering 4 Mean ± SD	*p* 1v2	1v3	1v4	2v3	2v4	3v4
Low DC n = 51	Con	2.50 ± 2.11	4.15 ± 1.41	4.61 ± 0.98	4.38 ± 1.50	.12	<.01*	.13	.50	1.00	1.00
	Com	2.58 ± 2.02	3.85 ± 1.41	4.78 ± 1.35	5.00 ± 1.41	.52	<.01*	.01*	.80	.80	1.00
	Enj	2.25 ± 1.9	3.31 ± 2.06	4.28 ± 1.78	4.00 ± 2.00	<.01	.09	<.01	.93	1.00	1.00
Medium DC n = 79	Con	5.96 ± 1.88	6.08 ± 1.38	6.03 ± 1.14	6.50 ± 1.00	1.00	1.00	1.00	1.00	1.00	1.00
	Com	6.04 ± 1.75	5.92 ± 1.55	6.26 ± 1.16	6.75 ± 0.96	1.00	1.00	1.00	1.00	1.00	1.00
	Enj	5.32 ± 2.18	5.69 ± 1.93	6.41 ± 1.92	8.50 ± 1.29	1.00	.39	.04*	.98	.19	.52
High DC n = 46	Con	7.43 ± 1.34	8.50 ± 0.58	7.32 ± 0.84	7.83 ± 1.17	.97	1.00	1.00	.92	1.00	1.00
	Com	7.64 ± 1.34	7.50 ± 1.73	7.73 ± 0.70	8.17 ± 1.70	1.00	1.00	1.00	1.00	1.00	1.00
	Enj	7.57 ± 0.94	8.00 ± 1.41	8.55 ± 0.80	9.50 ± 0.84	1.00	.90	.52	1.00	.98	.99

DC = Discipline Capacity, Con = Confidence, Com = Competence, Enj = Enjoyment, maximum reflection score = 10, **** significance at p = 0.05***

Grouped pre-unit assessment outcomes

Group pre-unit assessment scores are shown in Table 5. In the low DC group, there was no difference in pre-unit assessments in any offering other than significantly high scores in offering four than in either offering one (p < .01) or offering three (p = .05). There were no difference in scores in any offering for either the medium or high DC groups.

Table 5. Pre-unit assessment scores, grouped by DC and unit offering

	Offering 1	Offering 2	Offering 3	Offering 4	*p*					
	Mean ± SD	**Mean ± SD**	**Mean ± SD**	**Mean ± SD**	**1v2**	**1v3**	**1v4**	**2v3**	**2v4**	**3v4**
Low DC n = 51	5.08 ± .033	7.42 ± 2.64	7.44 ± 4.06	11.88 ± 2.59	.79	.69	***<.01****	1.00	.08	***.05****
Medium DC n = 79	8.43 ± 2.73	8.73 ± 2.91	10.53 ± 3.49	7.00 ± 0.82	1.00	.29	1.00	.85	1.00	.62
High DC n = 46	9.79 ± 2.36	9.50 ± 1.30	11.73 ± 3.53	10.00 ± 4.20	1.00	.82	1.00	.98	1.00	.99

DC = Discipline Capacity, maximum assessment score = 17, **** significance at p = 0.05***

Discussion

This study makes an important contribution through the development of a reliable metric incorporating student's self-assessment of their mathematical ability, factored by their previous learning in the discipline, and then provides a robust and easily deployed tool for classifying the students' mathematical ability prior to the commencement of a unit of study which so needed within the time compressed block teaching model. The robustness of this tool will then aid the rapid identification of students in low and medium groups, who are most in need of numeracy support activities in order to master and pass the subject. This is especially relevant to capture Victoria University's greater cohort of disadvantaged students to be able succeed. Furthermore, this is critically important within the time compressed teaching block of four weeks to allow academic staff the opportunity to respond by designing and allocating resources appropriately within, and outside, class times to directly target support to where it is needed most.

Discipline capacity assessment

Self-perceived capacity is in important marker for success in mathematics (Calvert, 1981) and other disciplines alike (Rozgonjuk et al 2020) (Parker, Trautwein, Marsh, Basarkod, & Dicke, 2020). This concept, espoused by Hart (1989), considers the multi-dimensional approach to mathematical learning, particularly with regards to how students feel about the unit and their capacity relating to the materials. Students with low perception of their ability are typically poorer performers in the discipline. In this study, as one might expect, the Low DC students were aligned uniformly with the lower questions relating to confidence, perceived competence, and enjoyment of the discipline. Reflecting Calvert's (1981) discussion around anxiety towards mathematics, the significantly lower confidence and perception of competence noted in the low DC group leads to a corresponding drop in unit enjoyment, presumably by creating a feeling of apprehension and dislike towards learning. Even in the medium DC group, the enjoyment score reflects a lower confidence competence level, suggesting a degree of extra caution, and possibly attention is also required for even this group of learners who one might reasonably expect to pass the unit. It is only in the high DC group that we see enjoyment levels corresponding to, and exceeding, that of both the lower groups thus painting a picture of a student without apprehension towards mathematical study and in whom pre-unit competence assessment would be expected to be higher.

Pre-unit assessment

As one might expect, the pre-unit assessment grades within this study aligned with the assessment tool groupings (low/medium/high). Results from this baseline quiz were significantly lower than that of the subsequent grouping with the expected outcome that the low DC group would fail assessment tasks should no intervention proceed.

Conclusion

Completion of mathematics, prior to undergraduate studies is declining. In the present study, use of the developed Discipline Capacity Assessment Tool (DCAT) has resulted in the identification of three distinct groups; low, medium, and high to delineate performance skill obtained from the pre-assessment quiz. Across the four independent offerings of this unit, there was no difference in DCAT classifications demonstrating the robustness of the tool and its application.

It is interesting to observe that the capacity score in the high DC group in offering three was significantly lower than that of offering one. While there may be a number of reasons for this, it can be seen that there was a higher proportion of students only completing intermediate level mathematics, along with lower self-reflected confidence, in this particular group and when compared to the other groups. Why this has occurred is not entirely clear but may perhaps relate to the slightly higher sample number in that offering, or that this was the first Covid-19 fully online digital offering of the unit (the unit was run face-to-face in 2019 and digitally in 2020). Given the uniformity across the other offerings however, this does not bias the outcome via underestimating the overall group and offering capacities across the study. This study involved students self-assessing DC by means of a pre-unit survey. The use of the three indices that of, perceptions of confidence and competence, as well as enjoyment is unique and builds on previous works around perception of proficiency (Green et al., 2017). The addition of a multiplying factor, relating to previous studies in the discipline, affords extra nuance in student classification via recognition that this learning may have a profound impact on student capacity, despite their perception. The DCAT allows for simple classification into low, medium, and high groups, with the performance of each student being reflected in pre-unit assessment scores. This suggests that the DCAT could be a useful approach to determine student capacity prior to commencing of teaching which may aid and provide an invaluable insight in the successful delivery of undergraduate mathematics.

Limitations and future research

The cohort of students captured here is limited to a narrow demographic, that of Victoria University in Melbourne. While this study is unique, the application of this metric needs to be replicated and validated within other universities that are under the same socio-economic, discipline, and block teaching pressure. A further limitation of this study is its sample size. It would be useful to see if the conclusions remain the same had the sample size been larger and ideally with a more balanced grouping across deliveries. Finally, it should be noted that due to the Covid-19 pandemic the second year of collection for this study (2020) was wholly delivered digitally in place of face-to-face learning. While it could be expected that any difference to student self-reflection is unlikely, there could well be a carry-over influence on DCAT scoring because of this delivery mode. This influence would be difficult to determine, but might be reasonable to expect more negative self-reflection arising from digital delivery of the first year units following a year of disruption and similar delivery at the culmination of secondary schooling. Having said this, the uniformity of the data would suggest no influence, even though the data includes both delivery modes.

Future directions for research relating to the DCAT might include the potential for deployment across other STEM disciplines to determine if the tool could aid in assisting students in such units to be more successful early in their academic years. Finally, investigation of the pairing of students with targeted extra-classroom activities based on DC group would provide extra insight into how best to aid students early in academic careers.

Disclosures

No conflicts of interest, financial or otherwise, are declared by the authors.

References

Bandura, A. (1977). Self-efficacy: toward a unifying theory of behavioral change. *Psychological Review, 84*, 191–215.

Boyd, W. E., Cullen, M., Bass, D., Pittman, J., & Regan, J. (1998). A Response to Apparently Low Levels of Numeracy and Literacy Amongst First Year University Environmental Science Students: A Numeracy and Literacy Skills Survey. *International Research in Geographical and Environmental Education, 7*(2), 106-121.

Buckley, S., Reid, K., Goos, M., Lipp, O., & Thomson, S. (2016). Understanding and addressing mathematics anxiety using perspectives from education, psychology and neuroscience. *Australian Journal of Education, 60*(2), 157–170. https://doi.org/10.1177/0004944116653000

Budgen, F., & West, J. (2018). Identifying and Supporting Numeracy Needs of First Year Undergraduate Education Students. *Athens Journal of Education, 5*(2), 131-144.

Calvert, E. L. (1981). *A Study of the Relationship between Level of Mathematics Anxiety and Sex, Age, Mathematical Background, and Previous Success in Mathematics.*ERIC

Chapin, L. A., & Oraison, B. (2019). *VU Kick Start: A pilot intervention for first-in-family university students.* . Paper presented at the STARS Conference 2019, Melbourne, Australia. . https://unistars.org/papers/STARS2019/04F.pdf

Crane, J., & Cox, J. (2013). More than Just a Lack of Knowledge: A Discussion of the Potential Hidden-Impact of Poor Pre-enrolment Science Background on Nursing Student Success in Bioscience Subjects. *International Journal of Innovation in Science and Mathematics Education, 21(2).*

Daker, R. J., Gattas, S. U., Sokolowski, H. M., Green, A. E., & Lyons, I. M. (2021). First-year students' math anxiety predicts STEM avoidance and underperformance throughout university, independently of math ability. *npj Science of Learning*, *6*(1), 1-13. https://doi.org/10.1038/s41539-021-00095-7

Daker, R. J., Cortes, R. A., Lyons, I. M., & Green, A. E. (2020). Creativity anxiety: Evidence for anxiety that is specific to creative thinking, from STEM to the arts. *Journal of Experimental Psychology: General*, *149*(1), 42. DOI: https://dx.doi.org/10.1037/xge0000630

Di Martino, P., & Gregorio, F. (2019). The mathematical crisis in secondary–tertiary transition. *International Journal of Science and Mathematics Education, 17*(4), 825-843. https://doi.org/10.1007/s10763-018-9894-y

Downie, C., Klein, R., & Sinnayah, P. (2019). *Using online tools to develop numerical competence in block mode teaching.* In *Proceedings of The Australian Conference on Science and Mathematics Education* (pp. 32-32).

Faulkner, F., Hannigan, A., & Fitzmaurice, O. (2014). The role of prior mathematical experience in predicting mathematics performance in higher education. *International Journal of Mathematical Education in Science and Technology, 45*(5), 648-667. https://doi.org/10.1080/0020739X.2013.868539

Green, S., McGlynn, S., Stuart, D., Fahey, P., Pettigrew, J., & Clothier, P. (2017). Assessment of numeracy in sports and exercise science students at an Australian university. *International Journal of Mathematical Education in Science and Technology, 49*(4), 571-587. doi:10.1080/0020739x.2017.1396625

Hart, L. (1989). Describing the Affective Domain: Saying What we Mean. In D. B. McLeod & V. M. Adams (Eds.), *Affect and Mathematical Problem-Solving: A New Perspective* (pp. 37-45). New York: Springer-Verlag.

Ingvarson, L., Reid, K., Buckley, S., Kleinheiz, E., Masters, G., & Rowley, G. (2014). *Best Practice Teacher Education Programs and Australia's Own Programs*.

Kennedy, J., Lyons, T., & Quinn, F. (2014). The continuing decline of science and mathematics enrolments in Australian high schools. *Teaching Science, 60*(2).

MacGillivray, H. (2009). Learning support and students studying mathematics and statistics. *International Journal of Mathematical Education in Science and Technology, 40*(4), 455-472.

Mallow, J. V. (1991). Reading Science. *Journal of Reading, 34*, 324–338.

McCluskey, T., Weldon, J., & Smallridge, A. (2019). Re-building the first year experience, one block at a time. *Student Success, 10*(1), 1-15.

Messinis, G., & Sheehan, P. (2015). *The academic performance of first year students at Victoria University by entry score and SES, 2009-2013.* . Victoria University, Melbourne. Retrieved from https://www.vu.edu.au/sites/default/files/cses/pdfs/the-academic-performance-of-first-yearstudents-at-VU-by-entry-score-and-SES-2009-2013.pdf.

Pajares, F. (1996). Self-efficacy beliefs in academic settings. *Review of Educational Research, 66*, 543.

Parker, P. D., Trautwein, U., Marsh, H. W., Basarkod, G., & Dicke, T. (2020). Development in relationship self-concept from high school to university predicts adjustment. *Developmental Psychology, 56*(8), 1547–1555. doi: https://doi.org/10.1037/dev0000992

Rozgonjuk, D., Kraav, T., Mikkor, K., Orav-Puurand, K., & Täht, K. (2020). Mathematics anxiety among STEM and social sciences students: the roles of mathematics self-efficacy, and deep and surface approach to learning. *International Journal of STEM Education*, *7*(1), 1-11.

Tariq, V. N., & Durrani, N. (2013). Factors influencing undergraduates' self-evaluation of numerical competence. *International Journal of Mathematical Education in Science and Technology, 43*(3), 337-356.

Timms, M. J., Moyle, K., Weldon, P. R., & Mitchell, P. (2018). Challenges in STEM learning in Australian schools: Literature and policy review.

Walker, R. (2010). Motivating science undergraduates: ideas and interventions. *International Journal of Innovation in Science and Mathematics Education, 18*, 1–13.

Weink, M. (2015). *Discipline profile of the mathematical sciences.* Melbourne.

Wilson, R., & Mack, J. (2017). Declines in high school mathematics and science participation: evidence of students' and future teachers' disengagement with maths. *Int J Innov Sci Math Educ, 22*(7), 35-48.

Wilson, T. M. (2013). Exercising QS: quantitative skills in an exercise science course. *International Journal of Mathematical Education in Science and Technology, 44*(6), 796-807. doi:10.1080/0020739x.2013.801524

Winchester, M., Klein, R., & Sinnayah, P. (2021). Block teaching and active learning improves academic outcomes for disadvantaged undergraduate groups. *Issues in Educational Research, 31*(4), 1330-1350. http://www.iier.org.au/iier31/winchester.pdf