Development of the *Self-Efficacy-Effort* in Mathematics Scale and its Relationship to Gender, Achievement, and Self-concept

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Mathematics self-efficacy is considered an important variable in mathematics education because of its links to mathematics achievement. This paper reports on the development of the *Self-efficacy-effort in Mathematics Scale* (SEEMS), an instrument that has strong theoretical and psychometric properties. Based on a sample of n = 224 Australian primary students and n =133 secondary students, the instrument demonstrated positive correlations with related measures of mathematics achievement and mathematics self-concept. Girls had higher mathematics achievement within the primary and secondary school data. There were no significant gender difference in mathematic self-concept scores for the primary and the secondary school students. For mathematics self-efficacy, a gender difference was only identified in the high school data. The implications of this research to mathematics education practices are reviewed in the paper.

Self-efficacy beliefs are people's judgments of their capability to accomplish a task or succeed in an activity (Bandura, 1997). Self-efficacy and self-concept are considered to be multidimensional constructs. The claim by Lau et al. (2018) is that students' academic self-efficacy beliefs influence: (1) their academic attainments; (2) how long students will persist and persevere when confronting difficulties; and (3) how resilient students will be in the face of adverse situations. Mathematics self-efficacy is considered an important agent in students' learning because mathematics self-efficacy beliefs help determine how much effort persistence, and resilience students will expend on a mathematics problem and/or activity (Mozahem et al., 2021; Zimmerman, 2000).

Self-efficacy, self-concept, and self-esteem belong to a group of self-belief variables identified as self-perception variables (Hay & Ashman, 2018). There are, however, subtle differences between these variables: self-concept is more descriptive (I am good at mathematics); self-esteem is more evaluative (I like mathematics) (Watkins & Dhawan, 1989); and self-efficacy is more effort (the doing) (I work hard at mathematics) (Sachitra & Bandara, 2017). Students' self-perception variables and their academic achievement are considered to be significantly correlated (Marsh et al., 2004). Mathematics self-efficacy is, however, deemed to have a higher correlation with mathematics achievement, than does mathematics self-concept (Pietsch et al., 2003). Certainly, mathematics self-efficacy is predictive of mathematics achievement and mathematics problem-solving (Pajares & Kranzler, 1995).

The evidence indicates there are gender differences related to mathematics self-concept, self-efficacy, and interest for both primary and secondary school students (Rodriguez et al., 2020). Boys generally have better motivation and self-perception profiles in mathematics, than do girls (Kurtz-Costes et al., 2008). In contrast, girls tend to exhibit fewer positive attitudes about mathematics and have higher rates of mathematics anxiety than their male classmates (Rodriguez et al., 2020). Within mathematics self-concept research, boys are more likely to rate themselves higher than girls, even when girls had equivalent or even higher mathematics achievement scores (Hay et al., 1989).

In terms of the assessment of a person's self-efficacy there has been the development of: (1) general measures, such as the Schwarzer and Jerusalem (1995) *General Self-Efficacy Scale* (example item "I can solve difficult problems if I try hard enough"); (2) academic self-efficacy measures, such as the Sachitra and Bandara (2017) *Academic Self-Efficacy Scale* (example item, "I make an attempt to meet the deadline for group assignments"); (3) and specific domain

2022. N. Fitzallen, C. Murphy, V. Hatisaru, & N. Maher (Eds.), *Mathematical confluences and journeys* (Proceedings of the 44th Annual Conference of the Mathematics Education Research Group of Australasia, July 3–7), pp. 266–273. Launceston: MERGA.

measures, such as in mathematics, "I work hard at mathematics" (Marsh et al., 2004).

Students' mathematics self-efficacy beliefs are assumed to form as students interpret and accept information from four sources (Lau et al., 2018): (1) mastery experiences (i.e., interpretation of one's performance in relationship to previous efforts and outcomes); (2) vicarious experiences (i.e., observing the actions and performance of peers and others who provide comparison information regarding one's capabilities); (3) social persuasions (i.e., verbal persuasion of capability from others in the social environment, such as teachers); and (4) physiological states (i.e., the interpretation of one's own physiological and emotional states as an indicator of capability, often associated with levels of anxiety). Self-efficacious students are considered to perceive themselves, rather than their teachers, as more responsible for their own academic learning outcomes (Zimmerman & Kitsantas, 2014). This supports the notion that students' self-efficacy beliefs are linked to their use of effort, as part of their mastery orientation to learning and their ability to self-regulate (Mozahem et al., 2021).

Rationale

There are a number of concerns associated with the assessment of students' self-efficacy in mathematics that have influenced the conceptualising of this research study. The first is, much of the previous self-efficacy research has focused on adults in the workplace, university students, and secondary school students (Bandura, 1997; Joët al., 2011). There has been less of a focus on specific subject domains, such as mathematics self-efficacy (Sachitra & Bandara, 2017). The second is more recent with self-efficacy researchers, such as Toland and Usher (2016) and Moriarty (2014) tended to shift the stem of the self-efficacy question from effort (I try hard) to confidence (I could). This was done, in part, to identify the student's confidence to complete a mathematical task just before doing that task. Confidence was considered an aspect of self-efficacy along with effort and persistence by Bandura (1997) but there is some unease associated with this perception. The first is, self-efficacy is an important determinant of academic performance, but the counter-position is that self-efficacy is merely a reflection of past performance (Talsma et al., 2018). The second is, academic achievement is influenced by effort plus high academic self-concept (Marsh et al., 2016). The third, relates to the notion that confidence is not the same construct as effort, with self-evaluation statements, such as "I am confident is mathematics" more related to self-esteem (Watkins & Dhawan, 1989).

The ability of an individual to self-evaluate and self-monitor their thinking and behaviour is considered a metacognitive skill (Weil et al., 2013) that involves students making a comparison of their performances and their emotional reactions over time (Schraw, 1998). When self-efficacy researchers shift the focus question to students' confidence with a task, they may be indirectly by asking students to make more of "higher order" metacognitive evaluation of their performance, a judgement which is considered more cognitively difficult for younger students to grasp (Weil et al., 2013).

The research evidence, particularly for younger students, lends more support to the use of effort questions when investigating self-efficacy. In addition, students' previous experiences and feedback with mathematics tasks has the strongest predictive influence on the formation of students' mathematics self-efficacy (Usher & Pajares, 2009). The main sources of this formation information comes from the social messaging provided by teachers to their students and the individual student's previous emotional and anxiety reactions as they engage with mathematics (Bandura, 1997; Joët et al., 2011).

The core aim of this paper then is to report on the development and the psychometric properties of a mathematics self-efficacy scale, the *Self-Efficacy-Effort in Mathematics Scale* (SEEMS), designed to address the concerns identified above. The items selected within this scale are orientated towards students' level of effort and persistence with mathematics and their participation in mathematics classes (Schwarzer & Jerusalem, 1995; Zimmerman, 2000).

Students' self-efficacy, self-concept, and academic achievement measures are correlated (Marsh et al., 2004), with gender having an influence on students' self-beliefs (Fyffe & Hay, 2021; Marsh, 1988) along with age (Mozahem et al., 2021). Thus, as part of the development and evaluation of SEEMS the following two research questions will be investigated:

How does the *Self-Efficacy-Effort in Mathematics Scale* (SEEMS) relate to students' mathematics self-concept and their academic achievement in mathematics? Does the *Self-Efficacy-Effort in Mathematics Scale* (SEEMS) identify any gender and or age differences within a cross-section of primary and secondary students?

Method

Ethical permission to conduct the research was provided by the relevant University and school authorities, with parents and teachers of the participating students also providing informed consent.

Participants: There were two participating groups. One group of participants were primary school students who were drawn from two co-education, non-government primary schools located in provincial Australian towns (n = 224, Years 3 to 6, mean age 10 years 5 months). The other group were secondary school participants who were drawn from one government high school in a provincial Australian town (n = 133, Year 7, mean age 12 years 4 months). All three schools clustered around the national socio-economic status (SES) school average, mean of 1000 as identified using the Australian Index of Community Socio Education Advantage (ICSEA, 2016). Data were collected in the mid to later part of the school year.

Instruments: The SEEMS was designed using relevant literature and the theoretical framework that: (1) self-efficacy pertains to students' use of effort and persistence with a task (Schwarzer & Jerusalem, 1995; Zimmerman, 2000); and (2) students' self-belief tests need to be designed so they are sympathetic to the students' ability to comprehend, interpret, and understand all items (Hay & Ashman, 2018; Weil et al., 2013). An initial bank of 15 survey items was generated and trialed with four teachers and 15 students from an independent urban primary school located in a middle socio-economic school district. Based on this feedback, items that were too similar to other items, or were not clearly interpreted by the students were either taken out or reworked. The end result was, the SEEMS, contained 12 items, focusing on students' effort and involvement in mathematics. The participants completed the SEEMS by selecting one of four Likert responses to each question (scored 1 to 4): Almost never like me; Usually not like me; Usually like me; Almost always like me.

The mathematics self-concept measure was extracted from the *Self-Description Questionnaire-1* (M-SDQ-1) (Marsh, 1988). The students read 10 declarative sentences related to mathematics (e.g., I'm good at mathematics) and selected one of five Likert responses: False; Mostly false; Sometimes false/sometimes true; Mostly true; or True. Marsh (1988) reported a Cronbach alpha reliability score of 0.89 for the M-SDQ-1.

The participating primary school teachers were asked to rate the mathematics ability of each participating student in their class, in relationship to the students' grade level achievements. To do this the teachers were provided with a rating scale from 1 to 10; 1 = poor performance, 5 = sound achievement, 10 = extremely high achievement. The participating secondary students' mathematics results were obtained from their school semester reports and converted onto the same rating scale identified above.

Procedure: The SEEMS and the M-SDQ were administered in-class time to the participating students in their regular class groups. Four weeks later, the SEEMS was re-administered to a cohort of 50 primary and 25 secondary students to investigate its reliability. All data were coded into SPSS (2016) for analysis.

Results

The SEEMS produced a high level of internal consistency (Cronbach alpha = 0.92) and a high level of test re-test reliability (r = 0.84) (Tabachnick et al., 2007). An exploratory factor analysis was conducted on the student data. The extraction method was principal component analysis, and the rotation method varimax with Kaiser normalization. The Eigenvalues scree plot identified that the 12 self-efficacy items formed two factors. Interpreting the output, the first factor identified (9 items) related to effort and trying hard in mathematics. The second factor related to students' involvement and participation in mathematics classes (3 items), as shown in Table 1.

Table 1
The SEEMS Factor Structure

SEEMS Items	Factors#	
	1	2
1. In mathematics I try hard.	.741	
2. I try hard to complete mathematics homework.	.772	
3. I try hard when given mathematics tests.	.808	
4. I am keen to answer teacher's questions asked of me about mathematics.		.787
5. I try hard to solve mathematics problems.	.749	
6. If I have a difficulty with a mathematics problem I keep working on it until it is solved.	.552	
7. I enjoy helping other students with mathematics.		.772
8. I want to finish class mathematics activities.	.612	
9. I like talking to the teacher about mathematics.		.822
10. I try hard to pay attention when the teacher is talking about mathematics.	.692	
11. I try hard doing workbook activities in mathematics	.789	
12. I study hard before a mathematics test	.575	

Note: #Factor loadings less than Eigenvalues 0.35 were suppressed

To further validate the internal structure of the SEEMS a Confirmatory Factor Analysis (CFA) was conducted using AMOS in SSSP (2016). The fit indexes for the two factor model (reported above) were all high and above the 0.9 criteria point (Schreiber et al., 2006): Norm Fit Index = 0.968, Comparative Fit Index = 0.976. The Root Mean Square of Error of Approximation was low = 0.052 and below the 0.06 criteria point (Schreiber et al., 2006).

The students' SEEMS scores, their M-SDQ scores, along and their teachers' ratings their mathematical achievement in class were significantly correlated for both the primary school and secondary school students (Tables 2 and 3).

Comparing cohorts, secondary school students demonstrated somewhat higher correlation levels between mathematics achievement, self-concept self-efficacy (r around 0.4), than the primary school students (achievement, self-efficacy, and self-concept r around 0.3). Mathematics self-concept and mathematics self-efficacy were significantly well correlated for both the primary and secondary school students (r around 0.6).

Table 2
Primary Students' Correlation: Mathematics Achievement, Self-concept, and Self-Efficacy
n = 224 (Years 3–6) (** $p > 0.01$)

Mathematics	Achievement (in class)	Self-Concept (M-SDQ)	Self-Efficacy (SEEMS)
Achievement (in class)	1.00		
Self-Concept (M-SDQ)	0.28**	1.00	
Self-Efficacy (SEEMS)	0.35**	0.60**	1.00

Table 3
Secondary Students' Correlation: Mathematics Achievement, Self-Concept, and Self-Efficacy
n = 133 (Year 7) (** $p > 0.01$)

Mathematics	Achievement (in-class)	Self-Concept (M-SDQ)	Self-Efficacy (SEEMS)
Achievement (in class)	1.00		
Self-Concept (M-SDQ)	0.48**	1.00	
Self-Efficacy (SEEMS)	0.47**	0.56**	1.00

Gender was explored within the student data using independent ANOVAs with a Bonferroni adjustment. Girls in primary and secondary school were rated by their teachers as having higher mathematics achievement, compared to boys. In primary school, girls rated their mathematics self-concept and self-efficacy similar to the boys (Table 4). In secondary school, compared to boys, girls had higher self-efficacy but similar self-concepts scores to the boys (Table 5). Reviewing mean scores, boys dropped in mathematics self-concept and self-efficacy in the first year of high school, compared to their primary school scores.

Table 4
Gender Difference Primary Students: Mathematics Achievement, Self-Concept, Self-Efficacy

Mathematics	Boys *n* = 104		Girls *n* = 121		*F* (1,223)	Sig ** $p > 0.01$
	M	*SD*	*M*	*SD*		
Achievement (in class)	5.65	2.09	6.36	1.92	7.19	0.008**
Self-Concept (M-SDQ)	30.12	9.29	28.87	8.91	1.06	0.305
Self-Efficacy (SEEMS)	40.45	6.84	41.63	5.53	2.25	0.135

Table 5
Gender Difference Secondary Students: Mathematics Achievement, Self-Concept, Self-Efficacy

Mathematics	Boys *n* =74		Girls *n* = 59		*F* (1,131)	Sig ** $p > 0.01$
	M	*SD*	*M*	*SD*		
Achievement (in class)	3.55	1.48	4.21	.29	7.14	0.009**
Self-Concept (M-SDQ)	25.52	8.53	28.10	7.89	3.19	0.076
Self-Efficacy (SEEMS)	34.22	8.10	39.02	5.59	14.44	0.000**

Discussion

The psychometrics of the SEEMS were identified to be strong (Tabachnick et al., 2007). The exploratory factor structure of the instrument was reflective of its theoretical framework that associates mathematics self-efficacy with students' level of effort and participation in-class (Schwarzer & Jerusalem, 1995; Zimmerman, 2000). A confirmatory factor analysis of the SEEMS demonstrated strong fit indexes for the obtained two factor model (Schreiber et al., 2006). This research demonstrated that for mathematics there was a positive correlation between academic achievement, self-concept, and self-efficacy, which supports the notion that these three variables are interactive (Lau et al., 2018). Of note, mathematics self-efficacy had a higher correlation with mathematics achievement than with mathematics self-concept in the primary school data, which is similar to the findings of Pietsch et al. (2003).

For both primary and secondary school students a significant correlation was identified between SEEMS, M-SDQ, and students' mathematics achievement. Such a finding between self-perception and achievement is consistent with previous research (Marsh et al., 2004). The correlation between mathematics self-efficacy and mathematics achievement was stronger in the first year of the high school student data, compared to the correlation within the primary school student data. This may reflect that in the secondary school setting, first year students have to engage in higher levels of self-efficacy to adapt to a new and faster delivery of curriculum, to new teaching and assessment practices, to more demands in terms of homework and assessment, and higher expectations (Hopwood et al., 2016). This links to previous self-efficacy research that as learning tasks become more difficult, students have to use more mastery orientation and self-regulatory strategies (Mozahem et al., 2021).

Gender was identified as a variable in this study. In mathematics self-concept research, boys are more likely to rate themselves higher than girls, even when girls have equivalent or higher mathematics scores (Hay & Ashman, 2018; Marsh, 1988). Watt (2004) noted that girls typically reported higher self-perceptions in English and boys typically reported high self-perceptions in mathematics. In this study, girls had higher mathematics achievement to boys but not higher mathematics self-concept. The gender results were more pronounced in the first year of high school, with girls having significantly higher achievement and self-efficacy scores. The hypothesis is that because mathematics self-efficacy and mathematics achievement are interactive and positively correlated, a change in one of these variables will influence the other (Mozahem et al., 2021; Zimmerman, 2000). On this point, Hyde et al. (1990) noted that over time, as male secondary students improved in their mathematics achievement scores, so too did their level of self-efficacy in mathematics improve. In this study girls had higher levels of mathematics achievement in primary and first year of secondary school, but similar mathematics self-concepts to the boys. The concern is that girls are more likely to transition away from engaging with mathematics and associated careers, not because they lack the ability but because of more negative gender social messaging and lower expectations associated with girls and mathematics (Goetz et al., 2013). This concern reflects Watt's (2004) statement that cautioned against concluding that in terms of academic and psychosocial well-being, it is the boys who are necessarily more at risk through secondary school, than the girls. Thus, helping all students to develop and grow their mathematics self-efficacy and engagement with mathematics needs to be a goal of education, with additional attention provided to students as they transition into their secondary school education.

Teachers have to actively teach mathematics content in a way that facilitates students' interest, motivation, and engagement with that content, which in turn facilitates students' self-efficacy and knowledge development (Hay et al., 2015). In addition, teachers also need to actively assist students to develop positive work, study and homework strategies that can assist students develop more of a mastery orientation to their learning (Schunk, 2012). Reducing

students' levels of anxiety associated with mathematics also needs to be a consideration, because mathematics anxiety has a detrimental influence on the development of a positive self-efficacy in mathematics (Joët et al., 2011). It is the negative and/or neutral social messaging that teachers, may unknowingly provide to students, that has the corrosive influence on their level of mathematics effort, performance, and anxiety (Goetz et al., 2013; Krispenz et al., 2019). Helping students to manage negative self-beliefs, such as anxiety and low self-efficacy typically involves a combination of social, behavioural, and cognitive interventions (Krispenz et al., 2019). Social messaging influences the formation of self-efficacy (Lau et al., 2018). Thus, teachers need to be mindful of their in-class conversations with their students, with less of a focus on the "the correct answer" and a greater focus on dialogue and constructive feedback with students about the processes of learning and students' use of strategies and effort (Callingham et al., 2019; Moni & Hay, 2019). At different points in their delivery of mathematics content, teachers need to raise topics, such as: students' fearfulness of making a mistake; students not wanting to be seen by peers as different or better; asking for help rather than giving up; homework and study strategies; and the application of mathematics across society. Positive messaging and informed feedback are for all students and certainly not restricted to the so called "good" mathematics students.

There are limitations associated with this study. The participants were drawn from three co-education schools located in a regional town in Australia, therefore, there may be specific factors associated with these students that may influence the generalisability of the findings. Different curriculum domains, such as English or science may react differently to mathematics in terms of students' self-perceptions and so this needs to be considered when interpreting and extending these findings. Future researchers could investigate how the SEEMS correlates to a mathematics confidence self-efficacy measure, as used by Moriarty (2014).

In conclusion, for students to be successful in mathematics, teachers need to engage in teaching the mathematics content and assisting all students to develop positive self-perceptions associated with mathematics. The evidence is students' mathematics self-efficacy is an important agent that directly and indirectly influences students' mathematics achievement. Thus, mathematics educators need to continue to actively encourage and support the development of positive self-efficacy in all of their students.

Acknowledgement: Dr Rosemary Callingham AM, University of Tasmania for advice when drafting the paper.

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