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ORIGINAL

Raising Primary School Boys' and Girls' Awareness and Interest in STEM-Related Activities, Subjects, and Careers: An Exploratory Case Study

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ABSTRACT

Internationally, there is an under-supply of intellectual capital to provide for STEM-related employment. One contributing factor is the low number of female students selecting STEM school subjects and careers. Despite the literature recommending students engage in STEM activities earlier, many initiatives are not implemented until high school. This paper reports on an Australian project named MindSET-do which provided students with early positive STEM experiences prior to high school to raise awareness of, interest in, and aspirations for STEM-related subjects and careers. The case study surveyed $n = 107$ Year 6 boys' and girls' interests, ability beliefs and expectations in STEM school subjects and careers. Students' awareness and interest in STEM-related subjects and careers increased significantly following experiences with inquiry-based STEM activities, $\chi 2(1, n = 107) = 4.57$ to 63.67, p < .05. Expectancy for success in mathematics was significantly higher for males than for females ($U = 1125$, $p = .044$, $r = .2$). Expectancy for success in science was slightly lower for the female group, but $p > .05$. Logistic regression found females were 24 percent less likely to have a positive view of mathematics than males ($p = .003$). Gender differences in STEM ability versus ability beliefs and expectancies for success are discussed, with recommendations for earlier positive experiences with STEM tasks.

Keywords GENDER STEREOTYPES, CAREERS, EDUCATIONAL OPPORTUNITIES, PRIMARY EDUCATION, QUANTITATIVE ANALYSIS

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1 INTRODUCTION

Since the Review of Australian Higher Education (Bradley, Noonan, Nugent, & Scales, 2008), the educational and career aspirations of Australian school students have been of interest to policy makers and university leaders (Gore, Holmes, Smith, Southgate, & Albright, 2015), with a focus on preparing students for STEM careers. The focus on STEM careers is a response to the national and international skills shortage in the rapidly

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expanding STEM industries (Jeffries, Curtis, & Conner, 2020; Office of the Chief Scientist, 2013). The Australian Industry Group (2015) noted that careers requiring STEM skills and knowledge constitute 75 percent of the fastest-growing occupations internationally. Due to the digitisation of society, STEM skills are increasingly required by employers across a broad range of occupations and this demand for STEM skills is likely to intensify in the future (BusinessEurope, 2018).

However, this demand is not being met by an increase in supply of STEM-focused secondary school graduates; rather, there has been a decline in the number of students enrolling in Science in Australian senior secondary schools. A similar trend has been identified for mathematics and information technology (Jeffries et al., 2020). This experience is reflected worldwide, where only 4.4% of United States, 13% of European, and 23% of Asian country undergraduate degrees were in Engineering (BusinessEurope, 2018) .

The term 'STEM education' used in this research is defined by the Education Council (2015) as "teaching of the disciplines within its umbrella –science, technology, engineering and mathematics– and also to a cross-disciplinary approach to teaching that increases student interest in STEM-related fields and improves students' problem solving and critical analysis skills" (p. 5). The STEM performance of students is often discussed in the separate learning areas of the Australian Curriculum: science, technologies, and mathematics (Murphy, 2020).

Internationally there is an acknowledged and substantial disparity between the proportion of males and females undertaking STEM subjects and aiming for STEM careers, with females having far lower representation (EngineeringUK, 2018; EU STEM Coalition, 2020; Normandeau, 2017; UNESCO, 2019). Despite females performing better than boys in STEM school subjects, girls are dropping out of the educational pipeline at every decision point (EngineeringUK, 2018). In 2016, Australia had the lowest proportion of females electing to take STEM subjects in school (27%) among countries in the Asia-Pacific region (Australian Academy of Science, 2019). The Australian Decadal Plan (2019) acknowledged that the role of the education system is to create a healthy pipeline of STEM students in which females choose STEM subjects.

There is a substantial body of research demonstrating that while females tend to match males' performance in mathematics and science during their teenage years, males tend to score more highly than females in their self-perceived ability and self-efficacy regarding mathematics and science (Aalderen-Smeets & Van Der Molen, 2018; Jeffries et al., 2020; Kurtz-Costes, Rowley, Harris-Britt, & Woods, 2008; Wang & Degol, 2017; Watt et al., 2017). Aspirations to pursue a career in science are not necessarily determined by students' aptitude in these fields; data from the Programme for International Student Assessment (PISA) identifies that even if boys and girls have similar scores in science, girls are less likely than boys to envision themselves in a science-related career when they are 30 (Normandeau, 2017). Similarly, it has been repeatedly reported that Australian females tend to be fearful and cautious when studying mathematics or physics, while males are more confident, and many females perceive that they have less ability than their achievements warrant in comparison with males who achieve the same scores (Jeffries et al., 2020; Office of the Chief

Scientist, 2016; Watt et al., 2017).

In Australia, the proportion of women represented in STEM careers has been declining (Workplace Gender Equality Agency (Australia), 2019). In 2016, of those working in the labour force with STEM vocational education and training qualifications, 92% were male and 8% female. The proportion of males (71%) to females (29%) in the labour force who hold university STEM qualifications is clearly unbalanced (Office of the Chief Scientist, 2020), making this gender gap a government priority (Dockery & Bawa, 2018). As noted by the Office of the Chief Scientist (2016), "girls and women represent untapped talent. Enabling them to realise their potential is about both economic growth and social justice" (p. 1).

A wide range of factors associated with the under-representation of females in the STEM domain have been identified in the research, including student self-perceived ability or confidence (Barth, Kim, Eno, & Guadagno, 2018), barriers to females in STEM careers (Dockery & Bawa, 2018; Microsoft, 2017; Normandeau, 2017), individuals' attitudes such as enjoyment, personal value and self-concept as well as their demographic background (Jeffries et al., 2020), and gendered negative stereotypes arising from parents, teachers and peers (Levy, 2017; Normandeau, 2017; Reinking & Martin, 2018). This suggests a complex problem without a single solution.

In response to the identified shortage of STEM-qualified workers (females in particular), the Australian government has identified the need to improve STEM-related education in various policy documents (Australian Academy of Science, 2019; Australian Curriculum Assessment and Reporting Authority, 2020; Australian Government Department of Education Skills and Employment, 2020; Education Council, 2015, 2019; Innovation and Science Australia, 2017). The Australian government has funded various programs to address the STEM gender imbalance but, as mentioned in the Decadal Plan (Australian Academy of Science, 2019) , it is difficult to determine the effectiveness of initiatives because the majority of gender equity programs in STEM lack formal evaluation. According to McKinnon (2020), 337 STEM initiatives have engaged girls and women in STEM in Australia, but a lack of evidence of impact for these initiatives means that it is unknown whether the desired policy outcomes are being achieved. Similarly, the EU STEM Coalition (2020) emphasises the need for robustness and cross-country analysis in the comparison of existing approaches and practices in STEM education, especially as it relates to the intervention logic of programs.

Whilst Year 10 remains the point in Australian schooling when students choose their stream (university or non-university) and when most careers education is provided (Cardak & Ryan, 2009), research suggests that, for some, career choices may be aspired to in Year 7, or as early as Year 5 (Archer, Dewitt, & Wong, 2014; BusinessEurope, 2018; EU STEM Coalition, 2020; Gore et al., 2017; Hartung, Porfeli, & Vondracek, 2005; Raciti & Dale, 2019; Van Tuijl & Van Der Molen, 2016). As summarised by Van Tuijl and Van Der Molen (2016), children as young as eight years of age are prematurely excluding STEM-related study and work options, due to negative images they have of the field or negative ability beliefs.

Despite the literature recommending students engage in STEM activities earlier, many initiatives are not implemented until high school. The Australian project reported in this study aims to provide students with early positive STEM experiences prior to high school to raise awareness of, interest in, and aspirations for STEM-related subjects and careers.

1.1 The Study

The theoretical perspective informing this research on young males and females engaging with STEM-related activities is the expectancy-value model (Eccles et al., 1983; Wigfield & Eccles, 2000, 2020). This theory postulates on the reasons for individuals choosing to engage or disengage with different activities and how these factors impact achievement behaviours, academic performance, subject choices, and career trajectories.

The expectancy-value theory (Eccles, 2011; Eccles et al., 1983), provides insight into learners' gendered beliefs about ability that influence STEM education choices and career aspirations. Eccles and her colleagues propose that two sets of beliefs, expectancies for success and the value children place on various behavioural choices they have, influence their preferences for learning tasks, persistence on those tasks, the amount of vigour in carrying them out and expected performance. The expectancy and value constructs are themselves influenced by psychological, contextual, social and cultural determinants, such as previous achievement experiences, socioeconomic life conditions, and gendered socialisation practices conveyed by parents and through teacher practices and peer relations (Aalderen-Smeets & Van Der Molen, 2018; Wigfield & Cambria, 2010).

Expectancies for success are defined as "children's beliefs about how well they will do on an upcoming task or further into the future" (Wigfield & Cambria, 2010, p. 38). Ability belief is defined as a person's assessment of his or her current competence at a given activity. Ability beliefs are distinguished conceptually from expectancies for success, as ability beliefs are focussed on the present ability and expectancies for success are focused on the future (Wigfield & Eccles, 2000). In the context of this study, the Year 6 students' confidence reflects the degree of certainty in their ability beliefs to code or to do STEM projects. Eccles and Wigfield (2020) associate achievement task values with the motivational aspects and the quality of tasks and how those qualities influence the person's desire to undertake the task. Achievement task values, which are subjective, comprise attainment value, intrinsic value, utility value and cost. Attainment value relates to the importance placed on doing well on tasks. Intrinsic value is apparent when the motivation for engaging in and completing a task is the enjoyment one gains. Utility value or usefulness refers to how tasks fit into a person's future plans or aspirations. Cost refers to what a person has to sacrifice in order to complete the task, or the anticipated effort required to complete the task. Cost was not a variable of interest in this study because the focus was on positive motivational aspects of task values generated through activities that were known to be enjoyable for young students.

The reviewed literature suggests that sociocultural factors, internalising gender-stereotypical thinking developed in the home, school, and the community, expectancies for success and the beliefs and values a child holds, are often critical determinants of achievement-related STEM education and career choices, which can start exerting their influence at an early age. Therefore, the perspective of Eccles et al. (1983) developed expectancy-value theory has been chosen to provide a lens through which to evaluate the level of effectiveness of the MindSET-do project.

The authors of this paper, from a regional Australian university, were successful in obtaining Higher Education Participation and Partnership Program (HEPPP) funding to support a STEM initiative (Australian Government Department of Education Skills and Employment, 2020). The project engaged Year 6 students with novel uses of technology to raise awareness of, interest in, and aspirations for STEM-related high school subjects that could lead to STEM careers. The program was designed to focus on the critical juncture between primary and secondary schooling, when, as some research suggests, attitudes towards STEM education and career decisions are strongly influenced (Gore et al., 2017; Raciti & Dale, 2019).

2 MATERIAL AND METHODS

The aim of the project was to provide an engaging program to develop Year 6 students' interest in STEM subjects at school and in STEM careers. The associated research was designed to evaluate: 1) the extent to which gender predicated attitude formation, and 2) the extent to which the program's aim of switching students on to STEM was achieved. To these ends, the following research questions were developed:

1. Is there a difference between Year 6 male and female expectancies for success in STEM school subjects?
2. Is there a difference between Year 6 male and female perceived task values experienced in the STEM activities?
3. Is there a difference between Year 6 male and female perceived achievement in the STEM activities?
4. Can early STEM experiences raise awareness of, interest in, and aspirations for STEM-related high school subjects and careers?

Participants were selected by purposive sampling, comprising n = 107 Year 6 students (53 female and 54 male, 10 to 12 years of age) from regional South-East Queensland primary state schools who volunteered to participate. The study had university human research ethics approval and Education Queensland approval and was conducted in accordance with all required ethics protocols. Participant confidentiality was maintained, and all data were de-identified. Parents of all children who agreed to participate in the study provided their informed written consent.

The Year 6 project consisted of three lessons aligned to the Year 6 Science and Digital Technologies curricula. The lessons were designed to deliver the content with a cross-disciplinary approach to increase student interest in the STEM activities. The lessons' inquiry-based activities required students to utilise knowledge, understanding and skills in science, technology, electrical engineering, and mathematics to problem-solve and design solutions to a real-life problem. The lessons were designed to be delivered in schools by male and female preservice teachers. Preservice teachers delivered the lessons so that school students could work closely with current university students who were role models for the types of opportunities available at university. All participating preservice teachers were trained to use an inquiry-based approach as the pedagogy for the three lessons.

Inquiry-based learning builds from a natural process of inquiry in which students experience a 'need to know' that motivates and deepens learning. Inquiry-based learning requires guidance from the teacher in the role of facilitator: providing structure and support for students as appropriate to their developmental stage (Rosicka, 2016).

Further, the preservice teachers were instructed to ensure that informal conversations about 21st century skills and STEM careers were held while the students engaged in the activities. These types of targeted conversations are usually not held with Year 6 students but were implemented in the lessons to raise the students' awareness of the value of studying STEM subjects at secondary school and the pathways to university.

During the three lessons, the Year 6 students engaged in innovative investigations into electrical circuitry and C++ coding, using Arduino UNO microcontrollers, breadboards, and light-emitting diodes (LEDs) which were provided to the schools for the lessons. The use of Arduino and C++ coding in Year 6 is not commonly offered in primary schools and they were specifically chosen so that the equipment and learning content would be a new experience for most students in the lessons.

A survey was used to capture male and female students' expectancies for success in STEM-related school subjects, achievement, and achievement task values in STEM-related activities. Quantitative and qualitative methodologies were employed within the survey through closed and open questions. The survey was delivered online to the Year 6 students at the completion of three lessons within their own school, yielding a total of 107 valid responses. The survey responses were analysed using descriptive and inferential statistics with SPSS, and qualitative comments from open-ended questions regarding expectancy beliefs about science and mathematics were categorised as binary variables (positive/negative).

Initial explorative analysis of the survey data revealed that the data were non-parametrically distributed. We selected the appropriate statistical procedure to test the null hypothesis of no difference in attitudinal responses between the male and female groups with nonparametric, ordinal scale data: the Mann-Whitney U test, using the mean of the ordered ranks as the measure of central tendency (Gibbons & Chakraborti, 2011). Odds ratios determined from logistic regression were also used to determine the likelihood of the male and female expectancy beliefs being positive when asked how well they would do this year in maths, and in science.

3 RESULTS

3.1 Research Question 1

Research question 1 asked: Is there a difference between Year 6 male and female expectancies for success in STEM school subjects?

The participants were asked two closed-choice survey questions concerning their expectancies for success in the STEM subjects of mathematics and science: 1) How well do you expect to do in maths this year? 2) How well do you expect to do in science this year? Closed-response options were ordinal: ranging from "not very well" to "extremely well". A larger number of females than males felt ambivalent about their mathematics and science outcomes (neutral response). A substantial proportion of females expected to do very well or extremely well in mathematics (43%) and science (36%), but this expectation was higher for males in both mathematics (65%) and science (43%).

A Mann-Whitney U test was conducted to determine the statistical significance of the mean difference in expectancy for success in mathematics and science between males and females (Table 1). Expectancy for success in mathematics was significantly higher for males than for females, with a small effect size[1] ($U = 1125$, $p = .044$, $r = .2$). Expectancy for success in science was slightly lower for the female group than for the male group, but this difference did not reach significance.

Table 1 Expectancy for success in mathematics and science by gender.

Survey question		*n*	Mean Rank	Sum of Ranks	Mann-Whitney	*Z*	*p*	Effect size (*r*)
How well do you expect to do in maths this year?	Male	54	59.67	3222	1125	-2.01	.044*	.2
	Female	53	48.23	2556				
How well do you expect to do in science this year?	Male	54	55.43	2993	1354	-0.516	.606	
	Female	53	52.55	2785				

For significant results, effect sizes are provided.

In relation to the expectancy questions in Table 1, "How well do you expect to do in maths/science this year?" participants were asked an additional open-response question to elicit a qualitative belief statement regarding their expectancies for success: "why do you feel this way?" The belief statements were then coded as either positive or negative. For example, a positive belief for mathematics was "because I think if I give it my best shot, I will succeed". A negative belief for mathematics was "because I am dumb". A positive belief for science was "because I love science and I love learning new things". A negative belief for science was "I am just no good at science".

Logistic regression analyses were performed to ascertain the effect of gender on expectancy beliefs (positive or negative), modelled in separate analyses for mathematics and science. For mathematics expectancy beliefs, the logistic regression model was statistically significant, $\chi^2(1) = 10.07$, $p < .01$. The model explained 13.0% (Nagelkerke R^2) of the variance in gender and correctly classified 64.3% of cases. Sensitivity was 100%, specificity was 84.6%, positive predictive value was 83.3% and negative predictive value was 46%. Odds ratios (Table 2) indicated that the female group was 24 percent less likely to have a positive view of mathematics than the male group ($p = .003$).

[1] A common effect size statistic for the Mann–Whitney U test is r, which is the Z value from the test divided by the square root of the total number of observations ($n = 107$). $r = .1 - < .3$ = small; $r = .3 - < .5$ = medium; $r \geq .5$ = large.)

For science, females and males' expectancy beliefs were not significantly predicted based on gender, confirming the non-significant difference result of the Mann-Whitney U test in Table 1.

Table 2 Logistic regression predicting likelihood of positive expectancy beliefs for mathematics based on gender.

							95% CI for Odds Ratio	
	B	**SE**	**Wald**	***df***	***p***	**Odds Ratio**	**Lower**	**Upper**
Gender	-1.449	.480	9.109	1	.003	.235	.092	.602
Constant	1.609	.387	17.269	1	0	5		

3.2 Research Question 2

Research question 2 asked: Is there a difference between Year 6 male and female perceived task values experienced in the STEM activities?

To determine the level of male and female perceived task values experienced after completing the STEM activities, the participants were asked to respond to the survey statements in Table 3. Mean ranks calculated from a Mann-Whitney U test showed that overall, males experienced greater task value than females; the difference was statistically significant for four out of the five statements for which the following small to medium effect sizes were calculated: "I enjoyed the Arduino lessons" ($U = 1100$, $p = .002$, $r = .2$); "I now think coding is a good skill to learn" ($U = 969$, $p = .002$, $r = .2$); "The lessons have influenced me to take STEM subjects at school" ($U = 998$, $p = .005$, $r = .3$), and "The lessons inspired me to think about a STEM career" ($U = 892$, $p = .001$, $r = .3$).

Table 3 Male and female perceived task values

Survey statement	**Gender**	***n***	**Mean Rank**	**Sum of Ranks**	**Mann-Whitney**	***Z***	***p***	**Effect size (*r*)**
I enjoyed the Arduino lessons	Male	54	60.13	3247	1100	-2.294	.022*	.2
	Female	53	47.75	2531				
My interest in circuitry and coding has increased	Male	54	59.26	3200	1147	-1.862	.063	
	Female	53	48.64	2578				
I now think coding is a good skill to learn	Male	54	62.56	3378	969	-3.077	.002*	.2
	Female	53	45.28	2400				
The lessons have influenced me to take STEM subjects at school	Male	54	62.02	3349	998	-2.793	.005*	.3
	Female	53	45.83	2429				
The lessons inspired me to think about a STEM career	Male	54	63.98	3455	892	-3.448	.001*	.3
	Female	53	43.83	2323				

For significant results, effect sizes are provided.

3.3 Research Question 3

Research question 3 asked: Is there a difference between Year 6 male and female perceived achievement in the STEM activities?

Two sets of pre- and post-program survey questions were posed to the Year 6 students regarding their perceived achievement in the two STEM tasks completed during the program. The first set of pre- and post-questions asked whether they could create an electrical circuit using a breadboard, LED lights, wires, and a battery pack. The second set of pre- and post-questions asked whether they were able to program LED lights on a breadboard to flash on and off using Arduino software. Descriptive statistics showing male and female achievement for each task are presented in Table 4 and Table 5.

Table 4 Male and female achievement gain in the task to create an electrical circuit using a breadboard, LED lights, wires, and a battery pack.

		Pre (counts)		Post (counts)		
		Yes	*No*	*Yes*	*No*	*Gain*
Gender	Male (n=54)	19	35	49	5	55%
	Female (n=53)	15	38	51	2	68%
Total		34	73	100	7	

Table 5 Male and female achievement gain in the task to code LED lights on a breadboard to flash on and off using Arduino software.

		Pre (counts)		Post (counts)		
		Yes	*No*	*Yes*	*No*	*Gain*
Gender	Male (n=54)	10	44	42	12	59%
	Female (n=53)	7	46	48	5	77%
Total		17	90	90	17	

Collectively, a large proportion of both the males and females reported a gain in achieving the learning goals of the two STEM tasks, with females reporting the greatest gain in both tasks. A McNemar exact test determined that overall, there was a statistically significant difference in the proportion of Year 6 students who self-reported that they could create an electrical circuit pre- and post-program, $p = .000$. The calculated odds ratio ($OR = 1.18$) showed that the students were 18 percent more likely to be able to create an electrical circuit after the program with a large Cohen's d effect size, $d = .65$.

A McNemar exact test also determined that there was a statistically significant difference in the proportion of Year 6 students who self-reported that they could program LED lights on a breadboard to flash on and off pre- and post-program, $p = .000$. The calculated odds ratio ($OR = 1.5$) showed that the students were 50 percent more likely to be able to do this after the program, with a large Cohen's d effect size[2] , d = .83.

While pre- and post-program gains in both STEM tasks were significant for both male and female groups, Chi-Square tests showed no significant difference between the male and females' perception of their post-program achievement in the two STEM tasks. In other words, both male and female groups reported equally positive achievement for both tasks.

Two survey statements associated with confidence in their ability to code, or to do STEM projects, were presented to participants in the post-program survey (5-point Likert; strongly disagree - strongly agree). The mean ranks results calculated from a Mann-Whitney U test (Table 6) show that males reported greater confidence than females in their ability to code ($U = 1128, p = .047, r = .2$). Males reported greater confidence than females in their ability to do STEM projects after the program, but this confidence measure did not reach significance.

Table 6 Overall confidence in ability

Survey statement	**Gender**	***n***	**Mean Rank**	**Sum of Ranks**	**Mann-Whitney**	***Z***	***p***	**Effect size**
Confidence in my ability to learn coding has increased	Male	54	59.6	3218.5	1128.5	-1.986	.047*	.2
	Female	53	48.29	2559.5				
Confidence in my ability to do STEM projects has increased	Male	54	58.78	3174	1173	-1.708	.088	
	Female	53	49.13	2604				

3.4 Research Question 4

Research question 4 asked: Can early STEM experiences raise awareness of, interest in, and aspirations for STEM-related high school subjects and careers?

To determine if the experiences with STEM activities during the MindSET-do school lessons had a positive effect on students' awareness, interest, and aspirations in STEM, four of the survey statements previously analysed in Table 3 for male/female difference in response were recoded from a 5-point agreement scale, collapsing the responses to two categories of "agreement" (agree and strongly agree) and "disagreement" (disagree and strongly disagree).

The results (Table 7) indicate that the STEM activities in Year 6 for both males and females resulted in an overall positive experience, with them being made aware of, and interested in, STEM for education and prospective careers.

Chi-Square tests determined that overall, there was a statistically significant difference in the proportion of Year 6 students who self-reported these positive beliefs and ambitions for STEM education and prospective careers in STEM. Based on the proportion of combined agree and strongly agree responses: 87% reported that their interest in circuitry and

[2]Cohen's d effect size was calculated from the odds ratio, using the formula $OR/1.81$ (Chinn, 2000). In terms of educational outcomes, d = .2 is considered a small effect size, d = .4, a medium effect size and d = .6 a large effect when measuring student achievement (Hattie, 2009) . An effect size of .4 sets a level where the effects of the treatment enhance achievement in such a way that an observable difference can be made (Hattie, 2012) .

coding had increased; 93% now thought that coding is a good skill to learn; the lessons have influenced 73% to take STEM subjects at school; and the lessons inspired 62% to think about a STEM career.

Table 7 Overall positive experience with STEM

Survey statement	Response	Freq.	Percent	Chi-Square	*p*
My interest in circuitry and coding has increased	Disagree	11	13	47.63	.001
	Agree	75	87		
I now think coding is a good skill to learn	Disagree	6	7	63.67	.001
	Agree	80	93		
The lessons have influenced me to take STEM subjects at school	Disagree	20	27	16.33	.001
	Agree	55	73		
The lessons inspired me to think about a STEM career	Disagree	30	38	4.57	.033
	Agree	49	62		

4 DISCUSSION

4.1 Expectancy for Success

The results indicate that expectancy for success in mathematics in Year 6 was significantly higher for males than for females. While the females tended to match males in their expectancy in science, males tended to score higher than the females in their ability beliefs in both mathematics and science. These results corroborate the findings of previous work in this field; while the females tended to match the males' performance in mathematics and science during their teenage years, males tended to score higher than females in their self-perceived ability regarding mathematics and science success.

This research confirms that gender-biased expectancies for success and ability beliefs in mathematics are emerging in primary school. In line with recent international research recommendations (Ganley & Lubienski, 2016; Rodríguez, Regueiro, Piñeiro, Estévez, & Valle, 2019), interventions to address female perceptions of confidence, expectations and ability beliefs in mathematics in particular, should be implemented earlier in the educational system than they are currently if longer-term changes to engagement with STEM careers for females are to materialise.

When asked why they felt this way about their expectancies for success in mathematics and science, the female group was 24 percent less likely to have a positive view of their expectancy in mathematics than the male group. These results are consistent with the literature and highlight the negative views some females have of their expected outcomes in mathematics as early as Year 6. The literature also reports the concerning finding that expectancy for success can be compounded by negative beliefs and that these beliefs can become increasingly negative over time.

When the belief statements were further analysed to explore motivational variables, both males and females had positive effort beliefs and learning goals. These were expressed in comments such as "Because Arduino has taught me to how to go back and fix problems more easily"; "Because the program increased my knowledge"; "I also have learnt math by this experience"; "Because I know more about coding Arduino". This was encouraging to see in the female cohort, especially when expectancies for success in mathematics and science and their confidence in those learning areas were generally lower than for males. One potential gender difference, which should be examined further in future research, was that in mathematics there was an absence of positive strategies given by the females, and in science these strategies were fewer in the female responses than in the male responses. This result suggests that modelling of successful learning strategies in mathematics and science may be beneficial for females.

Also of concern in the findings was evidence of negative effort beliefs, helpless attribution and avoidance strategies in mathematics and science for some males and females in Year 6. These findings are supported in the literature, which points to influences such as internalising gender-stereotypical beliefs, relative interest in mathematics and science, cultural stereotyping of mathematics as masculine, and the influence of societal factors (peer, family, teachers) (Archer et al., 2014; Kalpazidou-Schmidt & Cacace, 2019; McKinnon, 2020; Wang & Degol, 2017). To address these issues for female learners, multi-focused interventions are required with different stakeholders in the family, school, community, workplace, and with students.

4.2 Task Values

The valuing of learning tasks in primary school through to adolescence is domain-specific and can be formed by certain influences such as beliefs about how well an individual will do in an activity, their success or failure in them and whether their experiences with the activities were negative or positive (Wigfield & Eccles, 2020). These factors impact on their motivation and influence their choice to continue to engage in an activity. Positive experiences can evolve into learning pathways that influence academic achievement, choices and career interests. After participating in the STEM lessons, more males than females enjoyed the Arduino lessons, thought coding was a good skill to learn and were inspired to think about a STEM career. As a result, in the classroom, females may become disengaged during STEM activities and, subsequently, this may negatively affect their aspirations for STEM-related subjects in high school and for STEM careers. Hence, students reporting high task values for the Arduino lessons is a desirable outcome which can be fostered in the classroom to build and maintain interest in STEM activities, especially for females.

The findings indicate that the MindSET-do program had a positive effect on task values for STEM activities in the Year 6 cohort, although with different levels of effectiveness, and that both males and females developed an understanding of the usefulness of STEM in future careers. Research indicates that student interest and confidence in STEM subjects developing by the beginning of high school will continue and influence academic choices for university entrance (Sadler, Sonnert, Hazari, & Tai, 2012; Tai, Liu, Maltese, & Fan, 2006). However, as discussed in earlier studies and literature (Education Council, 2015; Van Tuijl & Van Der Molen, 2016), to develop females' STEM identity, engagement in STEM activities needs to be reinforced throughout their schooling to maintain a sense of how STEM can fit into their future plans. Based on the findings of this research, we propose that such engagement begins within primary school.

4.3 Achievement

The results showed very little gender difference in the students' self-reported level of achievement in the STEM activities. Survey responses to pre- and post-lesson activities revealed that the increase in knowledge about Arduino programming was statistically significant for the whole cohort. Students reported that they had learned how to create an electric circuit during the lessons and how to program LED lights. While collectively a large proportion of both the males and females reported a gain in achievement, females reported the greatest gain in both tasks.

Increased confidence stimulated by the inquiry-based, hands-on experiences with the STEM activities was a positive finding, but it is interesting to note that while both male and female groups reported equally positive achievement for both tasks, the males in the group reported greater confidence than females in their ability to code and their ability to do STEM projects after the program. These results are consistent with earlier studies and literature comparing males and females' STEM skill/confidence and confirm the disparity between ability and ability belief of females engaging in STEM activities (Aalderen-Smeets & Van Der Molen, 2018; Jeffries et al., 2020; Office of the Chief Scientist, 2016).

4.4 Importance of Early Intervention

To determine if raising awareness of, interest in, and aspirations for STEM-related high school subjects and careers in late primary school students is feasible with early positive STEM experiences, the discussion needs to consider students' expectancies for success, task values, achievement, and their reactions to positive experiences with STEM tasks. Our findings indicate that whilst males and females have similar STEM skills, females have lower expectancies for success, achievement task values and ability beliefs, which may impact their future STEM-related subject and career choices. Importantly, regarding interest in STEM-related activities, we found Year 6 males and females can be encouraged to develop an interest in STEM through engagement with stimulating hands-on activities, but Year 6 males develop a stronger sense of ability beliefs that enable them to be more readily interested in STEM than females in this year level. Of concern is the evidence of some students regarding their expectancy beliefs in mathematics and science, as the broader research suggests that negative experiences and mental baggage about achievement can have lasting negative effects (Blackwell, Trzesniewski, & Dweck, 2007).

On a positive note, Wigfield and Cambria (2010) also report that within a specific domain, such as mathematics or science, the achievement task values and ability beliefs identified by Eccles et al. (1983) can be distinguished in children by Year 5 and that these constructs change across ages. Hence, introducing STEM experiences earlier, and making females feel comfortable with these subjects from their earliest years, is critical if the outcome is to influence children's decisions to choose STEM-related subjects and value learning in STEM before they enter high school.

5 CONCLUSIONS

Analysis through the theoretical construct of the expectancy-value model (Eccles et al., 1983; Wigfield & Eccles, 2000, 2020) found that in this study, both Year 6 males and females can develop an interest in STEM through early positive engagement with an inquiry-based, hands-on STEM project. However, males developed a stronger sense of ability beliefs that enabled them to be more readily interested in STEM than females, even at the primary school level. The research indicates that the MindSET-do project positively influenced Year 6 male and female participants. As well as students reporting high levels of enjoyment, most importantly, both male and female students reported increased confidence when coding and engaging with the STEM activities, and increased intentions to undertake STEM subjects at school and to consider STEM careers. This accords with the Australian 2030 Commonwealth Report aim to lift Australian school performance in the STEM area and motivate students to develop skills required to succeed in the future workforce (Innovation and Science Australia, 2017).

The positive outcomes of the project highlight the importance of providing primary school students, in particular females, with early engaging experiences with STEM activities prior to high school, to instil positive beliefs in their ability and confidence in STEM. It is acknowledged that ability beliefs and confidence in relation to achievement in STEM activities are influenced by a myriad of societal factors (peer, family, teachers, community), and a series of choices based on children's expectancies for success, achievement task values, achievement, and gender stereotypes.

This research, however, found that raised awareness and changes to such values and confidence can be affected at the primary school level. We are now planning longitudinal studies to explore whether early, inquiry-based, hands-on experiences with STEM activities and STEM subjects prior to high school have positive effects on expectancies for success, task values and STEM education and career choices among students in the long-term, especially for girls.

6 AUTHORS' CONTRIBUTION

1. **Natalie McMaster:** Funding acquisition and investigation (lead); conceptualization, data curation, writing- original draft preparation, review and editing (equal).
2. **Michael David Carey:** Formal analysis (Lead); methodology (supporting); conceptualization, data curation, writing- original draft preparation, review and editing (equal).
3. **David Allen Martin:** Methodology (lead); formal analysis (Supporting); conceptualization, data curation, writing- original draft preparation, review and editing (equal).
4. **Janet Martin:** Project administration (lead); investigation (support); conceptualization, data curation, writing- original draft preparation, review and editing (equal).

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