International Journal of Engineering Education Vol. 27, No. 2, pp. 389–398, 2011
Printed in Great Britain
0949-149X/91 $3.00+0.00

Perceived Gender Differences in STEM Learning in the Middle School*

LYN D. ENGLISH
School of Mathematics, Science, and Technology Education, Queensland University of Technology, Australia.
E-mail: l.english@qut.edu.au

PETER HUDSON
School of Mathematics, Science, and Technology Education, Queensland University of Technology, Australia.
E-mail: pb.hudson@qut.edu.au

LES DAWES
School of Urban Development, Queensland University of Technology, Australia. E-mail: l.dawes@qut.edu.au

Women are underrepresented in science, technology, engineering and mathematics (STEM) university coursework, reflecting long-standing gender issues that have existed in core middle-school STEM subject areas. Using data from a survey and written responses, we report on findings following the introduction of engineering education in middle school classes across three schools (grade level 7, $n = 122$). The engineering experiences fused science, technology and mathematics concepts. The survey revealed higher percentages for girls than boys in 13 of the 24 items; however there were six items with a 20% difference in their perceptions about learning in STEM. For instance, despite girls recording that they have been provided equal or more opportunities than boys in STEM, they believed they do not do as well as boys (80% boys, 48% girls) or want to seek a career in STEM (39% boys, 17% girls). The written responses revealed gender differences across a number of themes in the students' responses, including resources, group work, the nature and type of learning experiences, content knowledge, and teachers' instructional style. Exposing students to STEM education facilitates an awareness of their learning and may assist girls to consider studying STEM subjects or STEM careers.

Keywords: middle-school engineering; student perceptions; gender differences

1. Introduction

Many nations are expressing concerns that the demand for skilled workers in science, technology, engineering, and mathematics (STEM) is increasing rapidly yet supply is declining. For example, the number of graduating engineers from U.S. institutions has slipped 20% in recent years [27, 28], while in Australia, the number of engineering graduates per million lags behind many other OECD countries [35]. To complicate matters, recent data reveal waning student interest in engineering, poor educational preparedness, a lack of diverse representation, and low persistence of current and future engineering students [10, pp. 13–20, 22]. These states of affairs are not surprising, given the declining participation in STEM subjects in the secondary school years, with most OECD economies witnessing a decrease in the percentages of STEM graduates for the last 20 years [1].

To fulfil the career gaps in Australia and other nations, more enrolments are needed in university engineering courses, including more diverse enrolments [13, pp. 425–437, 16, pp. 391–402, 25]. Women, in particular, are under-represented in engineering courses in various Western nations [11, pp. 211–226, 23, p. 439, 31].

One response to address the shortfall of engineers across several nations is the implementation of engineering education in the K-12 school years. Researchers in STEM education are exploring innovative ways to introduce school students to the world of engineering [7, pp. 38–41, 9, 22, 26, 39]. In this paper we address findings from the first year of a three-year longitudinal study in which engineering education is being implemented in grades 7 to 9. The engineering program introduces students and their teachers to foundational engineering ideas, principles, and design processes (which draw upon the students' existing mathematics and science curricula), and aims to foster students' and teachers' knowledge and understanding of engineering in society. Specifically, we report on male and female grade 7 students' perceptions of their classroom experiences in science, and their assessment of the engineering education program they experienced during the first year of the study. We explore the following questions:

* Accepted 18 January 2011.

1. What gender differences exist in students' perceptions of their classroom learning experiences in STEM? Specifically, what differences exist with respect to students' attitude and motivation, their confidence, the teaching methods experienced, the real-world connections made, and the assessment experienced?
2. What is the nature of the strengths and weaknesses identified by students in their assessment of the first-time engineering experiences, in terms of their interest, engagement, and learning outcomes?

2. Engineering education in K-12 classrooms

The proportion of year 12 students studying suitable enabling subjects in mathematics and science has continued to decline at the same time that shortages in engineering domains have emerged [2, 10, pp. 13–20]. Furthermore, the representation of women in engineering is still low, despite some efforts at the tertiary level to attract more female students (e.g., [12, pp. 261–264]). More than ever before, we need to increase the profile and relevance of mathematics and science education in solving problems of the real world, and we need to begin this in the primary and middle schools. The middle school has been identified as a crucial period for either encouraging or discouraging students' participation and interest in mathematics and science [34]. Engineering provides an exceptional context in which to showcase the relevance of students' learning in mathematics and science to dealing with authentic problems meaningful to them in their everyday lives.

Engineering education in the school curriculum is becoming increasingly important to the various fields of engineering and represents a new domain of research that brings together researchers from engineering, engineering education, mathematics education, and science education. In establishing this new field, researchers are posing a number of core questions that warrant attention, including: (a) What constitutes engineering thinking for primary/middle school students? (b) How can the nature of engineering and engineering practice be made visible to young learners? (c) How can we integrate engineering experiences within existing school curricula? (d) What engineering contexts are meaningful, engaging, and inspiring to young learners? and (e) What teacher professional development opportunities and supports are needed to facilitate teaching engineering thinking within the curriculum? [9, 10, pp. 13–20, 21, pp. 189–195, 22].

The introduction of engineering education in K-12 classrooms is a significant development here. In addition to helping students appreciate how their learning in mathematics, science, and technology can be applied to real-world problems, engineering education can contribute to better preparedness for upper secondary school subjects and can help students understand the roles and usefulness of the various fields of engineering. Enhancing students' interest in engineering as a career is also a key component of engineering education [20, 37, pp. 25–29]. Engineering education is furthermore lauded for developing students' abilities to think creatively, critically, flexibly, and visually, as well as learning to troubleshoot and gain from failure [14, 39].

3. Female participation in engineering

There have been mixed reports on the extent of women's participation in engineering and on how to effectively increase this participation. The majority of literature highlights concerns regarding women's low participation. For example, de Cohen and Deterding's [11, pp. 211–226] research involved extensive cross-sectional estimates of male and female student retention across U.S. universities. Their study found that overall and in most engineering disciplines there was no differential attrition by gender. Indeed, their data suggested that the retention of women at a national level and on average across engineering fields is no lower than male retention. Rather, their results suggested that the under-representation of women in engineering is driven largely by inadequate enrolment strategies. The researchers concluded that approaches to recruitment lie at the core of the severe under-representation of women.

There have been various recruitment drives, with many doing so through policy development and attempts to improve the university engineering curriculum [13, pp. 425–437, 38, pp. 447–451]. Du and Kolmos [13, pp. 425–437] reported on research that showed improving the learning environment, along with establishing new programs with more contextualized content, led to an increase in recruitment of women and a substantial appreciation of their learning. However, they argued that the expectations of such drives have only been partly met; they maintain that a bigger social change is needed here, one that includes many educational factors (e.g., university curriculum content, teaching methods) as well as the prevailing engineering culture. While we agree with their views, we maintain that efforts to increase diversity in engineering education need to look beyond these factors, namely, the STEM experiences students receive in the middle and high school years.

3.1 Motivation to enter engineering

Knowledge about the motivation to enrol in engineering courses, especially in the case of women [16, pp. 391–402], has been limited. Recent research by Smith and Dengiz [32, pp. 45–57], however, revealed that women enrolling in engineering courses in Turkey surpassed that of the U.S. To further investigate this finding, [32, pp. 45–57] administered a survey to 671 female students in several major universities in Turkey. The survey included questions pertaining to 'influence and feelings in the classroom and school environment,' a list of reasons for choosing engineering, statements about the environment for women engineering students, and questions that dealt with the students' future professional plans and further study [32, p. 48]. Of interest in their findings are the main motivators for choosing engineering. Forty percent indicated it was their enjoyment of the mathematical and technical concepts, while 21% claimed that they do well in these components. Gill *et al.*'s [16, pp. 391–402] study also indicated that across the range of engineering disciplines, success in science at school was a key factor in women enrolling in engineering.

As part of their study, they conducted focus groups [32, pp. 45–57] with 156 women (high school students, undergraduate students, graduate students, faculty members, and engineers in industry or government). Among the findings, undergraduate students indicated that the main influences in their selection of engineering courses came from their teachers, their parents and other relatives, and the media. Similar findings were reported by Du and Kolmos [13, pp. 425–437], where motives for choosing engineering were mainly an interest in science from high school and inspiration from their families. The high school focus groups of Smith and Dengiz's [32, pp. 45–57] research, students who planned to undertake university engineering courses, cited their primary reasons as the job opportunities available and their strengths in mathematics, science, and technology. Yet the gender differences in those entering careers in STEM are far lower for females than males.

This present study investigates gender differences in STEM learning within middle schools. It focuses on boys' and girls' attitudes, motivations, and confidence to be involved in STEM education. It also aims to analyze boys' and girls' STEM education experiences, in particular learning about engineering that may lead to engagement and interest in STEM subjects and possibly STEM career options.

4. Methodology

4.1 Participants and context

Middle school classes and their teachers from three Queensland (Australia) schools (two single-sex and one co-educational) participated in the first year of the study (grade 7 in 2009; grade 8 in 2010, grade 9 in 2011). In addition, given that one of the major difficulties in inspiring school students to consider engineering as a career is their lack of knowledge and understanding of the domain [10, pp. 13–20, 19, 29], this study includes participation by final-year undergraduate engineering students and science teacher education students from the Queensland University of Technology. The Queensland Department of Main Roads (Australia) is also an important industry partner, providing access for the schools to young engineers and showcasing interesting and best practice projects related to the engineering activities developed.

The engineering program in the first year included the following activities, which were developed in collaboration with the classroom teachers. Each activity highlighted the need for societal considerations in undertaking engineering projects as well as the importance of engineering design processes in completing such projects (cf. [24]). The program involved the following activities.

- The students were first introduced to the varied world of engineering and exposed to the different roles and societal responsibilities of engineers (two lessons of approx. 45 minutes duration).
- This activity was followed by 5–7 lessons that explored bridges and their construction. These lessons entailed: learning about the work of civil engineers including their important roles in society; exploring bridge structure with a focus on the main types of bridges in Brisbane, the students' home city; recognizing features/constraints of the main bridge types; investigating tension and compression, load distribution, reinforcement, strength, and their importance in bridge designs; describing, designing, and constructing a truss bridge with given constraints and materials; reflecting on the engineering design processes they used in constructing their bridge; reporting to the class explaining the steps to designing and building their bridge; and indicating what they could have done to strengthen their bridge.
- Following these activities, there were 3–4 lessons on boat building. These lessons focused on: exploring basic principles of boat design; designing and building a model boat; testing the buoyancy of the boat with the most weight (students choose materials, justify their choice, predict weight load, test prediction); reflecting on their design processes; reporting to the class with an explanation of their boat design, building, and testing; and finally, identifying what changes would have improved their boat.

The above activities focused on science and mathematics concepts, and also used technology to design and construct engineering structures.

4.2 Instruments and ANALYSIS

A post-test survey was administered to middle school students (n = 122) at the end of the first year of the study. The survey targeted students' perceptions of their classroom experiences in science (as displayed in Table 1), and was further elaborated upon with students' written evaluation of the engineering program of the first year. The survey was modified from those used by [4], which in turn drew upon the survey instruments of [15] and [30, 201–227]. The present survey was modified to focus on science with a refinement of some statements to improve clarity and lexical cohesion.

The survey comprised 24 statements using a five-part Likert scale. There were statements that established the context for learning in the school and statements to identify how students work in science and their relationships with their teachers. For instance, statement 3 says, 'My science teacher(s)

Table 1. Gender differences for item analysis (boys = 74, girls = 48)

Items	Gender	%*	*M*	*SD*
1. I'm encouraged to try new ways of thinking and doing things at school.	Boys	82	4.05	0.76
	Girls	90	4.15	0.58
2. School is where lots of new ideas and activities happen.	Boys	87	4.22	0.67
	Girls	94	4.33	0.60
3. My teacher shows me new ways of looking at and doing things.	Boys	77	3.99	0.97
	Girls	79	4.10	0.72
4. My science teacher expects us to work independently and to know what we are supposed to do.	Boys	61	3.65	1.00
	Girls	53	3.46	0.87
5. My science teacher tells me exactly which steps I must take to solve a problem.	Boys	69	3.85	0.97
	Girls	48	3.48	1.01
6. We have to memorize list of terms and/or formulae.	Boys	41	3.17	1.03
	Girls	17	2.71	0.94
7. In my science classes we often decide on our own ways to solve problems.	Boys	54	3.50	0.98
	Girls	73	3.81	0.64
8. In my science classes we are encouraged to ask lots of questions.	Boys	66	3.81	0.93
	Girls	75	4.06	0.95
9. In my science classes we relate what we are learning to everyday life.	Boys	61	3.69	1.01
	Girls	63	3.88	0.94
10. I enjoy what we do in science classes.	Boys	78	4.00	1.03
	Girls	69	3.98	1.14
11. I enjoy giving things a go in science, even if I don't know if they will work.	Boys	95	4.42	0.64
	Girls	81	4.17	0.78
12. I enjoy coming up with new ways of doing things in science.	Boys	77	3.93	0.82
	Girls	73	3.83	0.88
13. The science I am learning will be useful to me when I leave school.	Boys	64	3.76	1.18
	Girls	52	3.54	0.99
14. In science class, we talk about topics from other school subjects.	Boys	27	2.80	1.06
	Girls	50	3.42	0.92
15. We talk about things we experience outside of the class that are related to science.	Boys	58	3.58	0.94
	Girls	67	3.81	1.04
16. My science teacher allows me to cooperate with one or more other students to solve a problem.	Boys	80	4.01	0.88
	Girls	91	4.40	0.64
17. Students in my science class help each other before we ask the teacher for help.	Boys	37	3.09	0.98
	Girls	58	3.65	0.89
18. In my science class, I work with other students on projects or team assignments.	Boys	64	3.74	1.07
	Girls	85	4.32	0.78
19. Students in my science class help review the work of other students.	Boys	33	3.08	0.92
	Girls	46	3.46	0.77
20. It's important to do well in science.	Boys	86	4.24	0.87
	Girls	67	3.71	1.13
21. Science is useful in real life.	Boys	73	4.03	1.03
	Girls	77	3.98	0.81
22. I usually do well in science.	Boys	80	4.03	0.89
	Girls	48	3.52	1.01
23. I want to study science next year.	Boys	58	3.72	1.27
	Girls	41	3.19	1.28
24. I would like a job that involves using science.	Boys	39	3.24	1.32
	Girls	15	2.58	1.15

* Percentage agreeing or strongly agreeing.

show(s) me new ways of looking at and doing things.' The following three statements determine whether the students enjoy science (e.g., 'I enjoy giving things a go in science, even if I don't know if they will work.'). There were further statements about their enjoyment in science and how they work in the classroom with their teacher and their peers. Importantly, other information focused on their perceptions of achievement in science and whether they would seek further studies in science or a career in this direction. There were 122 completed surveys (74 males and 48 females). SPSS was used to elicit descriptive statistics (i.e., percentages, means [*M*], and standard deviations [*SD*]) and extract independent t-test statistics to compare males and females across the 24 items [17]. This tests the null hypothesis that there is no statistical significance between boys and girls (statistical significance would be less than 0.05). Using the statistical analysis package SPSS, Levene's test determines that equal variances were assumed ($p > 0.05$).

Students also completed a written evaluation of the engineering program, where they identified strengths and weaknesses of the program's activities. Students evaluated these activities in terms of their interest, engagement and learning outcomes, and were invited to add further comments on their experiences with the program. The students' responses were initially analysed to identify common themes, raised by the students; these data were then examined for patterns and trends using constant comparative strategies [33].

5. Results and discussion

Levene's test for equal variance assumptions was acceptable for all items except items 7, 18, 20 and 22, which were less than the recommended 0.05. Discounting these items, SPSS t-tests from the sample size ($n = 122$) showed a two-tailed statistical significance between males and females on eight items (i.e., 5, 6, 14, 16, 17, 19, 23, and 24, $p < 0.05$). Tests showed boys indicated higher statistical difference than girls about: the teacher telling them exactly the steps needed to solve a problem (Item 5), having to memorize terms and formulae (Item 6), studying science next year (Item 23), and wanting a job that uses science (Item 24). Girls, on the other hand, were statistically higher than boys for: talking about topics from other school subjects (Item 14), cooperating with one or more other students to solve a problem (Item 16), helping each other before they ask the teacher for help (Item 17), and helping review the work of other students (Item 19). It appeared that boys were oriented towards STEM careers more than girls, yet girls appreciated more collaboration for working in STEM.

Further descriptive statistics presented differences between girls' and boys' perceptions of their STEM learning. Percentage differences of 20% or more occurred in six items. For Item 6, only 17% of girls claimed they have to memorize terms and formulae compared with 41% of boys. Half the girls indicated that they talk about topics from other subjects in their science classes (27% for boys, Item 14) and 58% of girls claimed they help each other before they ask the teacher for help (37% for boys, Item 17, Table 1). Indeed, the girls indicated that they work with other students on project or team assignments more than the boys (64% boys, 85% girls, Item 18).

Percentages for girls were higher than boys in 13 of the 24 items. These included having the autonomy to decide on their own ways to solve problems (54% boys, 73% girls) and recognizing the usefulness of STEM in real life (73% boys, 77% girls). Items 16, 17, 18 and 19 relate to interactions with other students for which girls recorded higher percentages than the boys (Table 1). Even though girls perceived they were receiving appropriate pedagogical assistance in the STEM areas, they believed that they do not do as well as boys (80% boys, 48% girls). Despite recognizing STEM as useful, females also did not find STEM as important to achieve (86% boys, 67% girls) and were less inclined to pursue the study of STEM subjects (58% boys, 41% girls). In pragmatic terms, the learning of STEM subject areas would have more relevance if students do well in these subjects or would like a career in STEM. Yet, less than half the girls indicated they do well in science while this percentage was 80% for boys. Moreover, as few as 15% of girls would consider an occupation that involves science, including an engineering career; this was in contrast to boys (39%, Table 1). Interestingly, the 2008 Carrick Institute Report, Addressing the Supply and Quality of Engineering Graduates for the New Century indicated that the number of domestic female participation in engineering undergraduate degrees overall in Australia is around 15%.

5.1 Program evaluation

Data analysis revealed that most of the students' responses addressed the following themes: resources (materials and human), group work, challenging and motivational activities, hands-on experiences, connection to the real world, content knowledge, and teacher explanation and involvement.

5.2 Resources (materials and human)

There was considerable appreciation of the teacher and teaching from the girls. There were also comments about using materials and field trips as a way to engage female students, for example, 'Excursions: sparked interest in engineering.' Two girls made mention of the use of the resources for constructing an engineering activity: 'When we didn't put enough straws in to hold up the weights,' and 'We should have made the bridge a bit taller and stronger.' The boys, however, appeared to be more focused on resources compared with the girls, particularly with respect to what resources were useful and not useful. 'The websites/videos to consolidate the design' were indicated as a strength of the activities. The limited materials were criticized by many boys: 'Should have used different materials for making the bridge so we get a better understanding of bridges' and 'It was hard using the limited amount of materials.' Indeed, a wider variety of materials was recognized by the boys as a way to develop more realistic designs, although their comments did not highlight the importance of considering both design processes and materials. 'When we were making the bridge we couldn't use wood,' 'I didn't like what we made the bridge from,' and 'We only were allowed to use straws which were weak.' It appeared the main criticism was from the boys with 'not enough materials to use,' that lead towards the bridge not being 'strong enough.'

5.3 Group work

Girls tended to place more emphasis on personal relationships and building up group work when evaluating their learning. For example, one girl said she 'liked working in a group and expressing our ways of working together,' while another stated, 'Got us to build a stronger relationship with the people we worked with; got to combine all our ideas together.' There was some appreciation of the teacher allowing group work as the girls were 'trusted to work in groups.' However, there was also a comment that group work requires collaborative planning otherwise it could be detrimental to learning: 'When people go ahead with plans I have no idea what is going on. Also when people don't listen to me it is very frustrating.'

Boys had mixed responses about group work. They provided a few positive comments about group work: 'I enjoyed working with a team' and 'It improved our teamwork skills.' 'I liked co-operating with other people and learning that building a bridge isn't as easy as people make it look on TV.' However it was also noted that group work can cause difficulties, for instance: 'I liked working with my friends and also finding out new information about shapes. I disliked being with one person because they did nothing to help us' and 'People trying to get their own way' within the group work. Clearly, there is the need to address team work as a significant component in engineering education, which is aligned with constructivist principles of social interaction and hands-on experiences to raise learning standards [36].

5.4 Challenging, interesting and motivational activities

Engaging students in learning is key to their development. The activities needed to be challenging, interesting, and motivational for active-minded adolescents. Only two girls, however, commented on the level of engagement. One girl generalized that, 'All students were mostly engaged in the program' and another commented that the engineering activities allowed her to 'think and problem solve about how to make our bridge stronger and not break so easily.' The competitive aspect of the bridge-building project was considered to increase their enjoyment. Three boys also highlighted their engagement in the activity as confidence building about their learning, for instance: 'Great way of learning; boosted my and other people's confidence; opened my mind and made me feel better about coming to science and learning new things.' One boy wrote that these activities 'made me enjoy science.'

However, unlike the girls, the boys were quite critical of the challenge associated with the activities, to illustrate: 'activities could be a bit harder' and 'the fact that there are no obvious benefits to the students for participating in the program.' A few boys mentioned the need to stay on task and the problematic behavior of others, which was not evident in the girls' comments. For instance, they stated: 'I have some weaknesses in working on assignments and I am easy to get distracted;' 'Poor behavior of students in group;' and 'They can make you want to play with things and causes you to lose your attention to the teacher.' This insight into boys' and girls' behavior may provide a way to address key issues. For example, a teacher can then determine pedagogical strategies that may facilitate behavior in groups and ways to not 'play with things.' Despite a criticism of the activities being more purposefully directed on tests and achievements ('Could have used time better for normal class work'), overall, the boys indicated that the activities were interesting and motivational, for example, 'It was an enjoyable experience and boosted my confidence a lot.'

5.5 Hands-on experiences

The hands-on experiences were only mentioned by two girls. One wrote that it was 'fun to learn in experimental ways; sometimes I learn more when I do things rather than listen.' Another claimed: 'Hard and I didn't really enjoy them' but 'enjoyed experiments and boat building.' However, one girl commented that the 'Practical expts (sic, experiments) enabled me to understand the principles of engineering on a higher level.' These somewhat mixed responses were unlike the boys' comments, which were focused on the hands-on experiences: 'Fun to learn in experimental ways; sometimes I learn more when I do things rather than listen.' Differences between boys were also noted with the two types of hands-on activities (i.e., boat building and bridge building). For instance, one boy claimed, 'Well I found some activities pretty boring but I really enjoyed the boat activity' while another stated, 'I found that my strengths lie with bridge building.' Various male students were also more dissatisfied with their end products than the girls: 'We did not put in any support under the bridge straws to support it' and 'I didn't like how our bridge was built and I would try it again if I could.' Hands-on experiences were recognized by most as a way to learn by both boys and girls, which is in keeping with other studies [5, pp. 295–303, 6, pp. 301–309].

5.6 Connection to the real world

Learning connected to the real world provided insight for some students. Two girls wrote that the activities: 'Taught me importance of engineering in real life. Helped me wonder why things work,' and 'really opened my eyes to what engineering really is.' There was mention from boys about real-world connections, which included making links to local examples of engineering, for instance, 'The subject of bridges in Brisbane was fun.' One male noted the connection to careers in the real world: 'Science is my favorite subject and since I want to be a marine biologist it will help a lot in the future and my teacher helps me to learn a lot.' Real-world connections tended to make the activities more viable and usable for the students. As these experiences can open their eyes to engineering it may lead to a career choice for both boys and girls (e.g., [6, 301–309]).

5.7 Content knowledge

Many girls focused on the content knowledge within the activities with two commenting that they 'Learnt about bridges and other things (what structures of a bridge are most effective)' and it 'Helped us a lot in understanding the way forces work and why forces must be balanced in most things.' The levels of engagement and interest may be attributed to the challenge of understanding the concepts: 'Building a bridge wasn't as easy as I thought it would be, it was educational.' Three girls claimed that they did not like the 'bridge activity and found it annoying that nobody was helping them;' did not enjoy 'reading and writing answers for the test;' and disliked 'the activities as doesn't like science.'

The importance of eliciting prior knowledge was indicated by a few girls who were attuned to the content knowledge of the bridges unit of work, for example, the 'program was exciting but not much learned, as already knew it.' Two students were blatant about their lack of understanding of science and therefore their lack of interest in the topic: 'The fact I don't get science very much' and 'past my understanding—lost interest.' Conversely, another girl stated, 'prefer theory rather than practical.' The boys highlighted content knowledge as an important aspect of their learning: 'Specific content: forces and tension,' and 'I know how to build bridges etc. I can write a scientific term for most things easily and I can draw designs easily.' Many boys claimed the activities helped them with content knowledge, for example, 'It helped with science' but 'would rather do work that helps me for the tests.' There were boys who claimed the mathematics was too difficult and were self deprecating: 'Maths is too hard! I am too dumb to get it' and 'Maths is very complicated.' Another boy stated that he aims, 'to try my hardest. What I do wrong is panic a lot.' This signifies the pressures some students may feel when engaged in STEM activities. These signifiers need to be examined in longitudinal studies to determine why particular students would discount engineering as a career choice. Critical comments from students may provide insight into their future educational and employment prospects.

5.8 Teacher explanations and involvement

Although nearly all students were appreciative of their teachers' involvement, including the teacher's way of explaining science so it can be remembered, one girl claimed that the 'teachers should have checked on the students while building bridge to make sure everyone had fair go.' There was only one male statement about the teacher's involvement, namely, 'our teacher is the best science teacher I had all my life. Now I understand why bridges work and how boats float.'

6. Discussion

The students in this study indicated gender differences in their perceived learning in STEM areas. Surprisingly, girls' perceptions were higher than boys on just over half the survey items. Students' evaluation of the engineering program displayed an awareness of their learning including working with peers, the task design and resources, their class teacher's instructional style, and the connections to 'real-world' engineering. Students' awareness of their learning and their performance was evident across all the themes identified in the data analysis. For example, some students noted that they did not make best use of the resources provided; others commented that their understanding of bridge design would have been enhanced if different materials were provided. Female students in particular, were aware of their learning when participating in group work, emphasizing the importance of constructive collaborative planning and the integration of ideas from all group members. A couple of female students noted that the hands-on experiences enabled them to understand engineering principles better.

Male students referred to their engagement in the activities as a motivation for learning and to increase their confidence in STEM. Some male students identified weaknesses in their own learning styles and highlighted the need for productive and collaborative group work. The use of hands-on experiences as a way of improving their learning was also recorded by male and female students. Students' awareness of their learning was also seen in their comments on the content knowledge of the activities, with some students, boys in particular, identifying specific content they had learned. There were a couple of male and female students who displayed self-deprecating comments about their learning abilities in mathematics and science.

Further evidence of students' focus on the task designs and resources was found in their comments on the materials provided and on the perceived level of difficulty of the activities. Male students frequently claimed that the materials were too limiting and, if a wider variety of materials had been supplied, they would have been able to develop more realistic designs. A few students felt the activities were not sufficiently challenging. Nevertheless, students appreciated their teachers' instructional styles, commenting on the clarity of their explanations in facilitating learning. Finally, learning that is connected to 'real-world' engineering was appreciated by several students.

7. Limitations

The findings reported here come from a limited sample of middle school students attending non-state schools. All three schools enthusiastically support their students' learning in the STEM areas. Our findings and conclusions might well have differed had we incorporated a wider range of schools in different socio-economic regions. There were four items on Levene's test for equal variance assumptions that did not meet the requirements; hence a larger sample size with a more equitable distribution between males and females may result in clearer results on these items. Students' written responses were quite detailed and forthcoming in their critique of the STEM program. However, interviewing students would have provided deeper explanations emanating from the written responses. Such interviews would present details about their STEM learning, educational needs, and career prospects and, importantly, how to cater further for each gender when teaching and learning about STEM.

8. Concluding points

The survey findings suggested that, despite apparent equal opportunities for both boys and girls, boys perceived themselves as more successful in science subjects and wanted to learn science more than girls. Furthermore, boys considered STEM careers and pathways more viable than girls. A series of lessons within programs may not be sufficient to 'equalize' boys' and girls' perceptions of themselves in STEM areas. Changing perceptions may require programs that target girls at younger ages with consistency throughout an education system.

Forging STEM pathways for students will require teachers to have ongoing professional development in STEM areas. Providing STEM career options may also need to be embedded in such programs so students can see clearly the pathway opportunities. Engagement in STEM activities may provide a way for both genders to consider STEM pathways in their career choices.

Career prospects abound in STEM areas in Australia, however, there are insufficient students entering such courses to supply the employment market. Females are largely underrepresented in these courses. It may well be that their attitude to STEM study is a key factor here. It may also be that exposure to STEM learning and the rich opportunities it provides will increase the uptake of STEM careers. Increased female participation in university engineering education (involving undergraduate and graduate students, as well as teaching staff) can also 'increase the diversity of engineering knowledge, practice, innovative products, values, and engineering culture' [13, pp. 425–437]. Teacher support in choosing a male-dominated career such as engineering might also increase female participation, especially for those students who do not have family connections with the profession. Clearly, further studies are needed to determine how STEM education may instill confidence in females to perceive themselves as successful in these subjects, which may lead towards considering STEM pathways and careers.

Acknowledgements—The project reported here is supported by a three-year Australian Research Council (ARC) Linkage Grant LP0989152 (2009–2011). Any opinions, findings, and conclusions or recommendations expressed in this paper are those of the authors and do not necessarily reflect the views of the ARC. We wish to acknowledge the keen participation of the students and their teachers, as well as the excellent support provided by our research assistants, Jo Macri and Lyn Nock.

References

1. J. Ainley, J. Kos, and M. Nicholas, *Participation in science, mathematics, and technology in Australian Education. Research Monograph No. 63*. Australian Council for Educational Research, Camberwell, Victoria, 2008.
2. F. Barrington and P. Brown, Articulation between secondary mathematics and tertiary education programmes. *National Symposium on Mathematics Education for 21st Century Engineers*, RMIT, 7th December 2007.
3. D. J. Bee, B. S. Puck, and P. D. Heimdahl, Summer technology and engineering preview at stout (STEPS) for girls, *Proceedings of the 2003 American Society for Engineering Education Annual Conference & Exposition*. Nashville, Tennessee, June 2003.
4. T. Byers and L. Dawes, Out of the square and into reality—bringing secondary school mathematics and science into the real world, *Australian Association for Mathematics Teachers' National Conference*, Hobart, July 2007.
5. P. Cantrell and J. Ewing-Taylor, Exploring STEM career options through collaborative high school seminars, *Journal of Engineering Education,* **98**(3), 2009, pp. 295–303.
6. P. Cantrell, G. Pekcan, A. Itani, and N. Velasquez-Bryant, The effects of engineering modules on student learning in middle school science classrooms, *Journal of Engineering Education,* **95**(4), 2006, pp. 301–309.
7. B. M. Capobianco and N. Tyrie, Problem solving by DESIGN, *Science and Children,* **47**(2), 2009, pp. 38–41.
8. Carrick Institute, *Addressing the supply and quality of engineering graduates for the new century*, The Carrick Institute for Learning and Teaching in Higher Education Ltd, NSW, Australia, 2008.
9. C. M. Cunningham and K. Hester, Engineering is elementary: An engineering and technology curriculum for children. In *Proceedings of the 2007 American Society for Engineering Education Annual Conference & Exposition*, American Society for Engineering Education, Honolulu, Hawaii, 2007.
10. L. Dawes and G. Rasmussen, Activity and engagement—keys in connecting engineering with secondary school students, *Australasian Journal of Engineering Education,* **13**(1), 2007, pp. 13–20.
11. C. C. de Cohen and N. Deterding, Widening the net: National estimates of gender disparities in Engineering, *Journal of Engineering Education,* **98**(3), 2009, pp. 211–226.
12. R. Dhanaskar and A. Medhekar, The gender gap in engineering education: A case study from Central Queensland University, *World Transactions on Engineering and Technology Education,* **3**(2), 2004, pp. 261–264.
13. X. Du and A. Kolmos, Increasing the diversity of engineering education—a gender analysis in a PBL context, *European Journal of Engineering Education,* **34**(5), 2010, pp. 425–437.
14. L. D. English and N. Mousoulides, Engineering-based modelling experiences in the elementary Classroom, In M. S. Khine, & I. M. Saleh (Eds), *Dynamic Modeling: Cognitive Tool for Scientific Enquiry*, Springer (in series, Models and Modeling in Science Education), 2010.
15. T. L. Fry, T. R. Rhoads, M. Nanny, and M. J. O'Hair, A survey of authentic teaching in secondary math and science classrooms. In *Proceedings of the 2003 American Society for Engineering Education Annual Conference and Exposition*, American Society for Engineering Education, 2003.
16. J. Gill, R. Sharp, J. Mills, and S. Franzway, I *still* wanna be an engineer! Women, education and the engineering profession, *European Journal of Engineering Education,* **33**(4), 2008, pp. 391–402.
17. J. F. Hair, R. E. Anderson, R. L. Tatham, and W. C. Black, *Multivariate Data Analysis with Readings*, 4th edn, Prentice-Hall, New York, 1995.
18. C. M. A. Haworth, P. S. Dale, and R. Lomin, Sex differences and science: The etiology of science excellence, *Journal of Child Psychology and Psychiatry,* **50**(9), 2009, pp. 1113–1120.
19. L. S. Hirsch, J. D. Carpinelli, H. Kimmel, R. Rockland, and J. Bloom, The differential effects of pre-engineering curricula on middle school students' attitudes to and knowledge of engineering careers. In *Proceedings of the 37th ASEE/IEEE Frontiers in Education Conference,* Milwaukee, Wisconsin, 2007.
20. L. Katehi, G. Pearson, and M. Feder, *Engineering in K-12 education: Understanding the status and improving the prospects,* The National Academies Press, Washington, DC, 2009.
21. J. P. Kuehner and E. K. Mauch, Engineering applications for demonstrating mathematical problem-solving methods at the secondary education level, *Teaching Mathematics and its Applications,* **25**(4), 2006, pp. 189–195.
22. M. Lambert, H. Diefes-Dux, M. Beck, D. Duncan, E. Oware, and R. Nemeth, What is engineering?—An exploration of P-6 grade teachers' perspectives, In *Proceedings of the 37th ASEE/IEEE Frontiers in Education Conference,* Milwaukee, Wisconsin, 2007.
23. A. J. Little and B. A. León de la Barra, Attracting girls to science, engineering and technology: An Australian perspective, *European Journal of Engineering Education,* **34**(5), 2009, p. 439.
24. Massachusetts Department of Education, Massachusetts Science and Technology/Engineering Curriculum Framework, Massachusetts Department of Education, Miaden, MA, 2006.
25. J. Mills, M. E. Ayre, and J. Gill, *Gender Inclusive Engineering Education*, Routledge, New York, 2010.
26. N. Mousoulides and L. D. English, Integrating Engineering Experiences within the Elementary Mathematics Curriculum, *Proceedings of the 2nd Research in Engineering Education Symposium.,* Queensland, Australia, 2009.
27. National Academy of Sciences, *Rising above the gathering Storm: Energizing and employing America for a brighter economic future*, National Academics Press, Washington, DC, 2007.
28. Organisation for Economic Co-operation and Development, *OECD Science, technology, and industry outlook 2006 (highlights)*, 2006, www.oecd.org/dataoecd/39/19/37685541.pdf. Accessed 11 December 2010
29. L. G. Richards, G. Laufer, and J. A. Humphrey, *Teaching engineering in the middle school: The Virginia Middle School Engineering Education Initiative*, FIE, Boston, MA, Accessed 6–9 November 2002 (http://fie.engmg.pitt.edu/fie2002/papers).
30. E. Roelofs and J. Terwel, Constructivism and Authentic Pedagogy: State of the art and recent developments in the Dutch National Curriculum in Secondary Education, *Journal of Curriculum Studies,* **31**(2), 1999, pp. 201–227
31. V. Rohatynskyj, W. Davidson, W. Stiver, and M. Hayward, *Obstacle to Gender Parity in Engineering Education*, Forum on Public Policy, 2008, Accessed 6 May 2010 http://www.thefreelibrary.com/Obstacles+to+gender+parity+in+engineering+education.-a0197721362.
32. A. E. Smith and B. Dengiz, Women in engineering in Turkey—a large scale quantitative and qualitative examination, *European Journal of Engineering Education,* **35**(1), 2010, pp. 45–57.
33. A. Strauss and J. Corbin, *Basics of Qualitative Research: Ground Theory Procedures and Techniques*, Sage, CA, 1990.
34. J. Tafoya, Q. Nguyen, C. Skokan, and B. Moskal, K-12 Outreach in an engineering intensive university, In *Proceedings of the American Society for Engineering Education Annual Conference & Exposition* (ASEE), 2005.
35. P. Taylor, *Fixing Australia's Engineering Skills Shortage*, EA Media Release 29 January 2008.
36. L. Vygotsky, *Thought and Language*, London, UK, The MIT Press, 1986.
37. R. C. Wicklein, Five good reasons for engineering design as the focus for technology education, *The Technology Teacher,* **65**(7), 2006, pp. 25–29.
38. A. William, Let's TWIST: Creating a conducive learning environment for women, *International Journal of Engineering Education*, **18**(4), 2002, pp. 447–451.
39. J. Zawojewski, H. A., Diefes-Dux, and K. Bowman, *Models and Modeling in Engineering Education: Designing Experiences for all Students,* Sense Publishers, Netherlands, 2008.

Lyn English is a professor of mathematics education in the School of Mathematics, Science, and Technology Education, Queensland University of Technology. Her areas of research include engineering education, mathematical modeling, mathematical reasoning and problem solving, statistical reasoning, and early mathematical learning. Lyn is a Fellow of The Academy of the Social Sciences in Australia and is founding editor of the international journal, *Mathematical Thinking and Learning*. Her recent books include *Theories of Mathematics Education: Seeking New Frontiers* (with B. Sriraman, 2010, Springer) and the *Handbook of International Research in Mathematics Education: Directions for the 21st Century*, 2nd edn, 2008, Routledge.

Peter Hudson's teaching career spans 32 years, including ten years as a school principal and lecturing at two universities. Most of his doctoral students focus on educational leadership, mentoring and science education. He was instrumental in devising and implementing new international courses (e.g., a new Bachelor of Education Studies Primary Science degree in Malaysia). His service includes work with the Australian Schools Innovation in Science, Technology and Mathematics (ASISTM) projects and the Australian Government Quality Teaching Program. Peter's mentoring model for mentors is at the forefront of his work in schools. He currently holds two Australian Research Council grants and is project administrator for a $1.45m Department of Education, Employment and Work Relations grant.

Les Dawes is an Associate Professor in Civil and Environmental Engineering at the School of Urban Development, Queensland University of Technology (QUT). He is also Director of Domestic Relations for the Faculty of Built Environment and Engineering and Editor for the *Australasian Journal of Engineering Education*. He has been involved in developing design based activities and creating learning environments incorporating experiential learning and school outreach for over 12 years. His areas of research include engineering education focusing on improving teaching methods to engage learners in engineering education better at both secondary and tertiary levels and protection of land and water resources. He has published the outcomes of teaching practices and outreach interventions in numerous Engineering Education journals and Engineering Education Conferences.