# Understanding preservice teachers' predispositions for teaching engineering education in Australian schools

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**Abstract:** *Engineering education is underrepresented in Australia at the primary, middle school and high school levels. Understanding preservice teachers' preparedness to be involved in engineering will be important for developing an engineering curriculum. This study administered a survey to 36 preservice teachers, which gathered data about their perceptions of engineering and their predispositions for teaching engineering. Findings indicated that the four constructs associated with the survey had acceptable Cronbach alpha scores (i.e., personal professional attributes .88, student motivation .91, pedagogical knowledge .91, and fused curricula .89). However, there was no "disagree" or "strongly disagree" response greater than 22% for any of the 25 survey items. Generally, these preservice teachers indicated predispositions for teaching engineering in the middle school. Extensive scaffolding and support with education programs will assist preservice teachers to develop confidence in this field. Governments and education departments need to recognise the importance of engineering education, and universities must take a stronger role in developing engineering education curricula.*

## Introduction

Curriculum and cultural reform in engineering education is very much on the agenda internationally. An immediate driver for this is the global professional engineering skill shortage. 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. Preparing preservice teachers to facilitate engineering education programs will contribute directly to the global economy, environment, security and health. As Dowling, Carew, and Hadgraft (2010) highlight, engineers take on far-reaching responsibilities such as working to optimise environmental, social, and economic outcomes of programs or products as well as interacting effectively with other disciplines and professions. Developing preservice teachers abilities to teach engineering will require knowledge of their understandings and dispositions for teaching in this field. It will also entail knowledge about how to facilitate teaching practices for engineering education. Generically, teachers need to have personal professional attributes, pedagogical knowledge, ways to motivate student learning, and an understanding of the complexities of curricula. Each of these constructs will be discussed as they pertain to the construction of a survey instrument to measure preservice teachers' predispositions for teaching engineering.

Teachers need personal attributes within a professional environment that help to facilitate learning (Vallance, 2000). There is also a relationship between teaching any subject matter and the teacher's attitude towards delivery of the subject (Nieswandt, 2005). Indeed, teachers who have a positive attitude towards teaching a subject can influence a student far more than one who has a negative attitude (Ediger, 2002). In addition, effective teachers reflect on their practices for improvement (Schon, 1983), part of which is seeking and accepting advice from colleagues, executives and other professionals who can advance their practices. Teachers must also update their content knowledge to assist students with current understandings on topics and key concepts (Hudson, 2006). Personal attributes that display a willingness to research and learn about current educational innovations can advance a practitioner's pedagogical position. A teacher's pedagogical knowledge is considered key for facilitating learning (Hudson & Ginns, 2007). Learning environments need to have a range of opportunities for both collaborative and independent studies. A key role for the teacher while activities are being implemented is the use of effective questioning (Skamp, 2007). Current educational advancements indicate that questioning techniques can mirror theoretical underpinnings to engage levels of thinking. Higher-order thinking questions can stimulate students' cognitive processes (Anderson & Krathwohl, 2001).

Student motivation is a key to learning. Teachers need to know how to motivate students for learning in engineering. Instilling positive attitudes about engineering can motivate students to consider engineering as a career option (Cheng, 2008). Although there are many ways to motivate students, and students have different internal mechanisms for self motivation, a teacher can motivate students by: (1) targeting their misconceptions about the topic or key concepts (e.g., Broek & Kendeou, 2008); (2) facilitating cooperative group work with interactive activities (Howe et al., 2007); (3) providing practical, real-world activities (Skamp, 2007); and (4) presenting them with real-world excursions related to the topic being studied (Hudson, 2007). The teacher must also be able to address students' questions about the topic or at least know how to assist the students with their inquiry. Many hands-on lessons (e.g., science, mathematics, and engineering) will require problem solving. Such problem solving usually involves teachers "thinking on their feet", particularly with troubleshooting the supply, access, and usage of resources. Assessing students' learning of concepts and processes, and evaluating the teaching and learning environments are a crucial part of engineering education. Some claim that engineering can be taught at the early school levels, as there are fundamental concepts that can be included in mathematics, science, and engineering (Oware, Duncan, & English, 2007). Fusing curricula such as science and mathematics as a way to further engineering education may also benefit middle-school students' learning in science and mathematics (e.g., Cantrell, Pekcan, Itani, & Velasquez-Bryant, 2006). Indeed, evidence suggests that engineering activities have enhanced learning in mathematics (English & Mousoulides, 2009).

Australian educators have been making efforts to stimulate secondary school students' interests in engineering (Dawes & Rasmussen, 2007). However, it is important to establish a new educational culture that develops the next generation of engineers (Downing, 2006). Although steps have been taken to invite scientists into schools for encouraging students to become motivated about engineering (Owens, 2000) and efforts have been made to stimulate student interest through one-off engineering challenges (e.g., Olds, Harrell, & Valente, 2006) and competitions (Sadler, Coyle, & Schwartz, 2000), a more serious arrangement is required if a nation is to prepare itself adequately to combat an engineering crisis. The acronym STEM highlights the bonding between science, technology, engineering and mathematics, and has been noted as an area of need in Australia. If engineering education is to be developed then it must commence at the preservice teacher education level. A first step then in advancing engineering education is to investigate preservice teachers' predispositions for teaching engineering in the middle school. The research question is: What are preservice teachers' predispositions for teaching engineering in the middle school?

## Context

This study involved 36 second-year preservice teachers at an Australia regional university campus at the beginning of their first science education curriculum unit. Previously, they had been involved in a mathematics and science discipline unit, which focused on science and mathematics content knowledge. First semester units also included an introduction to education, teaching in new times, and learning networks using computers, while second semester units involved visual and verbal literacy, Indigenous education, active citizenship and wellness, health and physical education. They receive no school experiences in their first year. There were 53% of these participants (male=17%, females=83%) who were mature-aged students in their second year of a Bachelor of Education (primary) degree with a middle years pathway. Only 3% have had any life experience involving engineering with 22% claiming mathematics was a favourite subject and 44% claiming science as a favourite subject. There were 14% from the 22% who recorded both mathematics and science as a favourite subject.

## Data Collection and Analysis

A survey was developed with items based on a literature review and administered to 36 preservice teachers. Responses were recorded on a five-part Likert scale (strongly disagree to strongly agree, and scored 1 to 5, respectively) and administered at the beginning of their science education coursework. Within the five-part scale, "uncertain" or a score of 3 allowed for the full range of possible responses. The 25-item survey was constructed within four predetermined categories, *a priori*, to assist in preliminary confirmatory factor analysis (CFA, Kline, 1998). Items from the survey (which will be presented at the conference, and were assigned to factors as follows:

Factor 1: Personal professional attributes – survey items 2, 3, 6, 11, 21
Factor 2: Student motivation - items 4, 10, 14, 18, 22, 24
Factor 3: Pedagogical knowledge - items 5, 8, 9, 12, 13, 15, 17, 19, 23
Factor 4: Fused curricula - items 1, 7, 16, 20, 25

The respondents had three semesters of teacher education with coursework that highlighted these four factors. For example, coursework has emphasised the importance of: motivating students by targeting their misconceptions (Item 4), instilling positive attitudes to motivate students (Item 10) and facilitating cooperative group work (Item 18; part of Factor 2 above). As these are underlying practices for teaching in any key learning area (e.g., mathematics, science), each item may also be related to teaching engineering. Using SPSS, data were subjected to data reduction by assigning items to a construct (i.e., factor). These same items were then tested for internal consistency using a reliability measure, Cronbach alpha, where scores over .70 are considered acceptable (Kline, 1998). These steps were repeated for each of the four factors. Hence, data from the survey describe aggregated patterns instead of building causal relations (Creswell, 2008). Data were analysed with descriptive statistics (percentages, mean scores, and standard deviations) along with the CFA. Communalities and variances indicated a relationship between the items and number of factors extracted for any give factor set. For example, Factor 4 had five items (1, 7, 16, 20, 25) and using SPSS these items were examined to note if one or more factors existed, and a Cronbach alpha score provided reliability for this factor. Eiguenvalues >1 were a measure to determine the number of factors extracted. Also scale mean scores were recorded with standard deviation for each factor by using "compute variable" in SPSS. Analysis of variance (ANOVA) was used to determine statistical significance (i.e., $p<.05$) for data indicated from survey items with gender, and mathematics experiences and science experiences. Finally, written comments collected from the survey were analysed for qualitative responses to provide further insight into quantitative data.

## Results and Discussion

Confirmatory Factor Analysis (CFA) indicated only one factor was extracted for three of the four constructs. The construct Pedagogical Knowledge had nine items, hence, it is probable that this construct is made up of two factors, which was also indicated by the Eigenvalue even though the second Eigenvalue was low (11.8, see Table 1). However, Cronbach alpha scores were all well above the required limit, including the score for Pedagogical Knowledge, which showed internal consistency in the survey responses. Considering the strong relationship between science, mathematics, and engineering, it was surprising that ANOVA found no statistically significant difference for participants' experiences in mathematics and any of the 25 survey items; and only three items (1, 21, 24) were significant ($p<.05$) for science. Furthermore, engineering is considered a male-dominated career and so it was equally surprising that ANOVA showed only four items (1, 20, 21, 22) were statistically significant for gender, which were also not aligned with any factor.

Table 1: *CFA, Eigenvalue and Cronbach Alpha Scores*

| Factor | *M* scale score | *SD* | Eigenvalue | % of variance | Cronbach alpha |
|---|---|---|---|---|---|
| Personal professional attributes | 3.62 | 0.84 | 3.40 | 68.1 | 0.88 |
| Student motivation | 3.69 | 0.79 | 4.19 | 70.0 | 0.91 |
| Pedagogical knowledge | 3.44 | 0.78 | 5.40* | 60.0 | 0.91 |
| | | | 1.06* | 11.8 | |
| Fused curricula | 3.43 | 0.78 | 3.47 | 69.3 | 0.89 |

*Two factors extracted for pedagogical knowledge

Analysing data from survey items within the four constructs (i.e., personal professional attributes, student motivation, pedagogical knowledge, and fused curricula) revealed that a majority of preservice teachers agreed or strongly agreed that they could have the personal professional attributes for teaching engineering activities in the middle school. Indeed, 77% claimed they would have a positive attitude with 86% indicating they would accept advice from colleagues on teaching engineering (Table 2). This shows a willingness to be involved in engineering education. Although a majority of preservice teachers believed they could motivate middle years students in engineering (e.g., 75% for learning engineering and 80% instilling positive attitudes), only 42% indicated they would be able to target their misconceptions about engineering with 39% able to provide practical real-world engineering activities (Table 2). In addition, more than 56% of these preservice teachers agreed or strongly agreed they had personal professional attributes for engaging in engineering lessons with many claiming they can motivate students into engineering (Table 2). Table 3 was similar in that participants indicated a range of responses. Hence, further analysis was required by including the percentage of "uncertain" responses in both Tables 2 and 3. The relatively high responses of uncertainty indicated the tentative nature of these preservice teachers for entering into the engineering education field.

Table 2: *Personal Professional Attributes and Student Motivation*

| Item with associated construct | *M* | *SD* | % agree | % uncertain |
|---|---|---|---|---|
| *Personal professional attributes* | | | | |
| 2. research a range of ideas | 3.61 | 0.84 | 58 | 36 |
| 3. enthusiastically facilitate lessons | 3.50 | 0.88 | 56 | 33 |
| 6. accept advice from colleagues | 4.19 | 0.86 | 86 | 11 |
| 11. confidently teach engineering | 2.94 | 0.79 | 61 | 17 |
| 21. have a positive attitude | 3.86 | 0.83 | 77 | 17 |
| *Student motivation* | | | | |
| 4. targeting their misconceptions | 3.39 | 0.84 | 42 | 47 |
| 10. for learning engineering | 3.83 | 0.77 | 75 | 22 |
| 14. instil positive attitudes | 3.83 | 0.70 | 80 | 17 |
| 18. facilitate cooperative group work | 3.67 | 0.79 | 66 | 28 |
| 22. practical, real-world engineering activities | 3.72 | 0.78 | 39 | 58 |
| 24. real-world excursions | 3.72 | 0.88 | 58 | 39 |

These preservice teachers had completed their last science education coursework for teaching in the middle school and, despite having little or no engineering experiences, 75% claimed they could use effective questioning strategies for teaching engineering (Table 3). Part of their science coursework included the use of Bloom's Taxonomy (Bloom, 1956) as a theory for developing higher-order questions in science. It seems likely that these participants believed they could transfer these questioning skills over to engineering education, which for all intents and purposes would be theoretically sound. However, less than half the preservice teachers believed they could assist students on independent studies (49%), solve problems to do with engineering education (44%), assess students' learning (39%), and address students' questions about engineering (27%).

Engineering involves the fusing of science and mathematics concepts. These preservice teachers agreed or strongly agreed that they could identify the science in engineering activities (53%) and apply scientific concepts (61%), yet a minority felt they could identify mathematics concepts (47%) and apply mathematics concepts (36%). These preservice teachers had completed one unit of mathematics, however, were to complete a further two units of mathematics. The disparity between perceived science and mathematics identification and application may be a result of their previous completed units in these subjects. Similarly, they had completed two technology units which may be indicative of the relatively positive response (56%, Table 3). Indeed, the correlation between curricula needs to be explored to determine what aspects within these subjects may facilitate confidence for teaching engineering.

Table 3: *Pedagogical Knowledge and Fused Curricula*

| Item with associated construct | *M* | *SD* | % agree | % uncertain |
|---|---|---|---|---|
| *Pedagogical knowledge* | | | | |
| 5. use effective questioning strategies | 3.81 | 0.82 | 75 | 19 |
| 8. select appropriate equipment and resources | 3.44 | 0.69 | 52 | 42 |
| 9. variety of teaching strategies | 3.56 | 0.73 | 55 | 42 |
| 12. independent studies | 3.31 | 0.83 | 49 | 40 |
| 13. evaluate my engineering teaching | 3.64 | 0.83 | 66 | 25 |
| 15. Address students' questions about engineering | 3.08 | 0.84 | 27 | 56 |
| 17. plan for teaching engineering-based activities | 3.44 | 0.81 | 49 | 42 |
| 19. solve problems | 3.28 | 0.78 | 44 | 50 |
| 23. assess students' learning | 3.39 | 0.73 | 39 | 58 |
| *Fused Curricula* | | | | |
| 1. apply mathematics concepts | 3.31 | 0.71 | 36 | 58 |
| 7. apply science concepts | 3.58 | 0.77 | 61 | 33 |
| 16. identify the mathematics | 3.36 | 0.80 | 47 | 42 |
| 20. identify the science | 3.44 | 0.84 | 53 | 36 |
| 25. use of technology | 3.44 | 0.77 | 41 | 56 |

## Conclusion

This study aimed to investigate preservice teachers' dispositions for teaching engineering in the middle school. Confirmatory factor analysis required more participant responses for accuracy of the reported statistics (e.g., see Kline, 1998). However, this study provided an indication that there may be factors associated with preservice teachers' perceptions of their predispositions for teaching engineering education in the middle school. This study highlighted that nearly all these preservice teachers either agreed or were uncertain that they would have the personal professional attributes or pedagogical knowledge, including fusing curricula with science and mathematics, for teaching engineering in the middle school. Similarly, they either agreed or were uncertain that they could motivate students into engineering, which means that many may be educated for changing their perceptions. Considering 22% claimed mathematics as a favourite subject and double that for science, it appeared that meeting these fundamental engineering education requirements will necessitate extensive scaffolding and support with education programs that assist preservice teachers to develop confidence in this field. Universities must take a stronger role in facilitating engineering education (Tafoya, Nguyen, Skokan, & Moskal, 2005). As preservice teacher education occurs within university settings, establishing engineering coursework will aid in facilitating this specialised field and in the long term increase student awareness of engineering as a career path.

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## Acknowledgement

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 excellent support provided by our research assistants, Jo Macri and Karen Nichols.