A pilot study on Engineering & Technology Education in Primary Schools

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Abstract*: This paper reports on the first phase of an Engineering Education action research project aimed at developing interest and understanding among primary school students in engineering and technology (E&T) as potential career choices in order to redress the inadequate supply of appropriately trained professionals. The research team in collaboration with students, teachers and school administrators worked on developing engineering curriculum modules to extend existing science curricula in primary schools. Participating students completed pre and post assessments that included questions about general E&T concepts. Analysis revealed that students had a limited understanding about E&T. Post assessments indicated statistically significant improvements to student understanding after exposure to the engineering curriculum. This research demonstrated a successful development to enhance and measure excellence in teaching and learning of E&T concepts at primary school students' level.*

Introduction

Australian society is becoming increasingly dependent on E&T, so it is important that citizens have a basic understanding of what engineers do, as well as the uses and implications of the technologies created. Research on elementary school children's ideas about E&T is sparse when compared with the literature available on science education (Lachapelle & Cunningham, 2007). The first stage of a school-based longitudinal research project is reported in this paper providing baseline data to relate to major stake holders initiatives under the national Research Priority of *Frontier Technologies for Building and Transforming Australian Industries.* The underpinning conceptual framework for the proposed study is innovative and draws together two significant research areas in primary education: E&T education; and learning environments.

Engineering and Technology Education

Despite massive advances in science, few citizens worldwide are technologically literate, largely because E&T are seldom taught in schools (Lachapelle & Cunningham, 2007). It is important to begin science instruction in primary school by building on children's curiosity about the natural world, and to begin engineering instruction by building on children's natural inclination to design, build and take things apart (Cunningham & Hester, 2007). It is essential that young people's interest in science and E&T is stimulated and maintained through schooling so that students continue with these studies at the university level in order to address the skills shortage (MCEETYA, 2006).

The national review of higher education (Bradley, Noonan, Nugent, & Scales, 2008) established that

Australia needs more qualified professionals, across a wide spectrum, to meet projected demand. Taylor (2008) also identified that Australia needs significantly more engineering graduates in the workforce to satisfy predicted growth needs and to achieve targets for economic and social progress. To increase the need for engineers, children must develop an interest in science, E&T throughout their school lives. Even though high-quality teaching of science in Australian primary schools is a national priority (Goodrum & Rennie, 2007), it has been recognised that some of the problems with declining numbers in student preferences in engineering stem from the lack of engagement with science and E&T in primary and secondary schools (Pearce, Flavell, & Dao-Cheng, 2010). Consequently, cultural and curriculum changes within the schooling system need to occur.

The proposed project, in collaboration with six Industry Partners, addresses this gap between theory and practice. No such study has been carried out previously in Australia.

Theoretical Framework

Learning Environment Research

The study drew upon the growing field of learning environments (Fraser, 2007). Contemporary research on school environments partly owes it's inspiration to Lewin's (1936) seminal work in non-educational settings, which recognised that both the environment and its interaction with the individual are potent determinants of human behaviour. The notion of person-environment fit has been elucidated in education by Stern (1970), and Walberg (1981) proposed a model in which the educational environment is one of nine determinants of student learning. The field of learning environments is identified with a variety of economical, robust and extensively validated questionnaires that measure different psychosocial dimensions of the classroom. These instruments are used to investigate the learning environment more closely from the perspective of the students who make up a classroom rather than from the perspective of trained observers or teachers.

One of the most promising applications of classroom environment assessments is their use as process criteria of effectiveness in evaluating educational programmes. In this study, we used learning environment criteria in evaluating the effectiveness of the implemented engineering programme.

Research Questions

The overarching aim of this project is to develop **interest and understanding among primary school students in engineering and technology (E & T) as potential career choices through creating engaging learning environments** in order to **redress the inadequacy of the pool of locally-trained professionals** in these fields and to satisfy demand. Further, the project aims to develop the E&T literacy of primary school students and teachers. The objectives of this study are:

1. To investigate what activities students classify as being E&T.
2. To further develop and validate an instrument to assess the students' learning environment and their understanding and interest in E&T.
3. To investigate year-level, gender and cultural differences in students' classroom learning environment perceptions and understanding and interest in E&T.
4. To assess the effectiveness of implemented E&T lessons in terms of the quality of the classroom learning environment and student understanding and interest in E&T.

Methodology

This research was guided by a practical action research methodology, distinguished by an iterative cycle of planning, action, observations and reflection (Creswell, 2003) and appropriate educational materials for E&T were developed, field tested and evaluated. The action research cycle is currently being repeated, with a wide range of participants providing feedback to the cycle.

The initial study involved 340 students from 15 primary classrooms in five schools in years 4, 5 and 6 in Perth, Western Australia. A survey instrument by Lachapelle and Cunningham (2007) was modified and implemented to assess students' understanding and interest in E&T. As only some of the photos were replaced, without changing the meaning of the concept illustrated, the validity of this instrument has not been changed, having a Cronbach alpha reliability of 0.71 for the Engineering section and 0.63 for the Technology section (Cronbach, 1951). After the survey, a lesson defining engineering and the importance of science, E&T was delivered by two of the authors (male and female) who are engineers by training. In addition, at least one engineering topic (two to three lessons), chosen by the class teachers, was taught in these classes. Researchers used lesson plans from 'Tryengineering' (www.tryengineering.org) as a guideline and modified them to fit local needs. Teachers were given the lesson plans, materials and any other support they needed for these lessons. These lessons were observed by at least one researcher. A post-test survey was administered to find any changes in understanding and interest in E&T. Table 1 represents the demographic information about the participating students in the study.

Table 1. Demographic information about the sample

School	Student No	Percentage of cohort (%)
1	67	19.7
2	77	22.6
3	69	20.3
4	54	15.9
5	73	21.5

Year	Student No	Percentage of cohort (%)
4	126	37.1
5	120	35.3
6	94	27.6

Parent engineer	Student No	Percentage of cohort (%)
Yes	33	9.7
No	307	90.3

Gender	Student No	Percentage of cohort (%)
Boys	147	43.2
Girls	193	56.8

Results

Quantitative Data: Perception of E&T

The survey probed children's perception of E&T, asking them 'What does an engineer do?' and 'What is technology?', and to draw examples of what an engineer does and what technology is, and to describe their pictures in words. The results indicated that students generally had a poor idea about the work of engineers while more than 60% had a stronger understanding about technology. Very few wanted to take up engineering related careers, however, an increase in student career aspirations as well as understanding of E&T shows in the post-test results (Table 2). To systematically probe student's perceptions of E & T, the questionnaire included captioned images of working people from which the students had to choose those that showed what an engineer would be expected to do at work, and other items that may or may not represent technology, while asking students, 'What is technology?' Both tests showed a significant shift towards selection of correct responses between the pre and post-test results (see Tables 3 and 4). As part of our evaluation of the E & T teaching, we examined the changes in students' perceptions that occurred during the instruction. Each wrong answer was marked as zero and right as one. The differences are described in Tables 3 and 4, in terms of effect size (i.e. the number of standard deviations), whereas a t-test for paired samples was used to determine the statistical significance of this difference. Effect Size, in terms of the differences in means divided by the pooled standard deviation ranged between 0.08 to 1.32 for the engineering test and 0.06 to 0.98 for the technology test. The effect sizes for the engineering questions were larger for most scales.

The engineering test recorded statistically significant changes in all item differences except for the items of 'work as electrician' and 'drive machine'. Similarly only three items demonstrated insignificant changes in pre-test/post-test differences in the technology test.

Table 2 Student work aspirations and understanding of Engineering and Technology

	Pre-test		Post-test	
	Student No	Percentage	Student No	Percentage
Work aspiration (What would you like to be when you grow up?)				
Engineering	26	7.6	35	10.3
Non engineering	314	92.4	260	76.5
No response			45	13.2
Engineering brainstorm (What does an engineer do?)				
No idea	9	2.6	2	0.6
Poor idea	170	50	10	2.9
Moderate idea	65	19.1	96	28.2
Sound idea	96	28.2	232	68.2
Technology brainstorm (What is technology?)				
No idea	11	3.2	3	0.9
Poor idea	20	5.9	4	1.2
Moderate idea	104	30.6	32	9.4
Sound idea	205	60.3	301	88.5

Table 3. Students' Perceptions on the items in the Engineering Questionnaire

Item	Item mean		Item SD		Differences	
	Pre-test	Post-test	Pre-test	Post-test	Effect size	t
Design circuits	0.69	0.87	0.46	0.34	0.44	6.21***
Make better food	0.02	0.09	0.13	0.29	0.32	4.33***
Design machines	0.75	0.96	0.43	0.21	0.68	8.26***
Better farming	0.15	0.37	0.35	0.48	0.52	7.86***
Design better phones	0.46	0.82	0.49	0.38	0.82	11.93***
Design MRI	0.44	0.78	0.49	0.41	0.77	11.23***
Design tablets	0.04	0.54	0.21	0.51	1.32	17.79***
Protect coastline	0.13	0.32	0.34	0.47	0.47	6.74***
Work as a team	0.57	0.83	0.49	0.38	0.59	8.56***
Make smaller recorders	0.31	0.67	0.46	0.47	0.77	11.02***
Design bridges	0.56	0.90	0.49	0.30	0.83	12.15***
Design space shutters	0.49	0.79	0.50	0.41	0.66	9.75***
Work as electrician	0.39	0.35	0.49	0.48	0.08	1.22
Build houses	0.59	0.48	0.49	0.50	0.22	3.27**
Drive machines	0.69	0.73	0.46	0.44	0.08	1.62
Repair machines	0.20	0.27	0.40	0.45	0.16	2.88**

Table 4. Students' Perceptions on the items in the Technology Questionnaire

Item	Item mean		Item SD		Differences	
	Pre-test	Post-test	Pre-test	Post-test	Effect size	t
TV	0.96	0.98	0.19	0.13	0.12	1.79
Train	0.76	0.89	0.43	0.65	0.23	3.41**
Running shoes	0.09	0.49	0.29	0.50	0.98	14.43***
Telephone	0.94	0.97	0.24	0.17	0.14	2.14*
Tea cup	0.05	0.12	0.21	0.33	0.25	4.58***
Manufacturing plant	0.62	0.78	0.49	0.41	0.35	5.57***
Refinery	0.54	0.75	0.49	0.43	0.45	6.52***
Computer	0.97	0.98	0.16	0.13	0.06	1.00
Bicycle	0.14	0.34	0.35	0.47	0.48	7.31***
Bridge	0.13	0.42	0.34	0.49	0.69	9.95***
Genetics (artificial arm)	0.31	0.47	0.46	0.50	0.33	5.31***
Spaceship	0.83	0.90	0.37	0.31	0.20	2.76**
Tree	0.98	0.96	0.13	0.19	0.12	2.12*
Bird	0.99	0.97	0.12	0.16	0.14	1.41
Lightening	0.76	0.64	0.43	0.48	0.26	3.93***
Ecosystem	0.89	0.80	0.32	0.39	0.25	3.66***

Year Level and School differences

The differences in students' understanding of the survey questions on the basis of year level they belonged to were analysed. Out of all questions of 'What Engineers do' questionnaire, 6 items showed statistically significant differences at $P<0.05$. From the 'What is Technology' questionnaire, 5 items showed statistically significant differences in students' understanding at $P<0.01$(Table 5).

Differences in students' understanding of the survey questions from different schools were also analysed. Seven items related to the 'What Engineers do' questionnaire and 8 items related to the 'What is Technology' questionnaire showed statistically significant differences ($P<0.01$) (Table 6).

Table 5. Item Mean, Standard Deviation and Significance of Difference between Means (t) for the statistically significant different items in the year level differences

Engineering Question Items	Item mean			Item SD			Difference
	Year 4	Year 5	Year 6	Year 4	Year 5	Year 6	t
Design circuits	1.40	1.27	1.29	0.49	0.44	0.45	2.95*
Design machines	1.30	1.30	1.17	0.46	0.46	0.38	3.27*
Design MRI	1.64	1.51	1.51	0.48	0.50	0.50	3.03*
Design bridges	1.50	1.48	1.32	0.50	0.50	0.47	4.21**
Work as electrician	1.67	1.66	1.52	0.47	0.47	0.50	3.18*
Drives machines	1.38	1.22	1.34	0.48	0.42	0.48	4.24**
Technology Question Items							
TV	1.08	1.02	1.03	0.27	1.15	0.17	3.03*
Tea cup	1.89	1.99	1.99	0.31	0.12	0.09	9.19***
Manufacturing plant	1.46	1.35	1.35	0.50	0.48	0.46	3.45*
Bicycle	1.80	1.89	1.89	0.40	0.32	0.29	3.52*
Bridge	1.79	1.92	1.92	0.41	0.27	0.28	6.23**

Table 6. Item Mean, Standard Deviation and Significance of Difference between Means (t) for the statistically significant different items in the school differences (S=School)

Engineering Question Items	Item mean					Item SD					Difference
	S1	S2	S3	S4	S5	S1	S2	S3	S4	S5	t
Design tablets	1.96	1.96	1.99	1.89	1.98	0.20	0.19	0.11	0.32	0.15	2.59*
Protect coastline	1.83	1.75	1.96	1.77	1.97	0.37	0.43	0.18	0.42	0.18	7.32***
Design bridges	1.42	1.31	1.45	1.42	1.58	0.49	0.46	0.50	0.49	0.49	3.15**
Work as electrician	1.55	1.74	1.56	1.73	1.57	0.50	0.44	0.49	0.45	0.49	2.88*
Build houses	1.48	1.43	1.24	1.55	1.38	0.50	0.49	0.43	0.50	0.48	4.13**
Drive machines	1.34	1.47	1.16	1.29	1.33	0.47	0.50	0.37	0.46	0.47	4.66***
Repair machines	1.69	1.94	1.78	1.79	1.80	0.46	0.25	0.42	0.41	0.40	3.71**
Technology Question Items											
Running shoes	1.94	1.91	1.93	1.73	1.98	0.23	0.29	0.26	0.45	0.15	8.02***
Tea cup	1.99	1.97	1.98	1.79	2.00	0.12	0.16	0.15	0.41	0.00	12.2***
Manufacturing plant	1.30	1.26	1.33	1.53	1.49	0.46	0.44	0.47	0.50	0.50	4.71**
Bicycle	1.85	1.88	1.88	1.68	1.97	0.36	0.32	0.33	0.47	0.18	6.80***
Bridge	1.83	1.90	1.89	1.76	1.94	0.37	0.31	0.31	0.43	0.23	3.2**
Genetics	1.73	1.53	1.78	1.76	1.69	0.45	0.50	0.42	0.43	0.47	3.62**
Tree	1.00	1.04	1.01	1.06	1.00	0.00	0.19	0.11	0.25	0.00	2.66*
Ecosystem	1.08	1.22	1.04	1.16	1.05	0.28	0.41	0.19	0.37	0.21	5.34***

Qualitative data

After running the E&T lessons, informal interviews were conducted with participating teachers and students. Denzin and Lincolin (1994) *bricolage* method influenced the research team while interpreting the information, which was collected using a variety of research methods. The research team drew on a various paradigms for data interpretation to help explain the cultural factors that could contribute towards the student understanding and interest in E&T. Qualitative data further strengthened our claim. Teachers recognised the need for E & T education and support. Both students and teachers felt that E&T education should be imparted to primary students. The main points, which emerged from the teacher and student interviews, were the need for expert support and the need for resources: teaching materials, relevant engineering education in primary schools books and provision of site visits.

Conclusions and future research plans

The results of the quantitative data show that there are huge gaps in the understanding of primary school students of E&T and these gaps serve as a deterrent to their motivation to take up an E&T related career. Students and teachers enjoyed the E&T lessons and statistically significant differences were recorded in students understanding in the post-test. Further work is continuing to incorporate research, evaluation and assessment into all aspects of curriculum design and testing from its inception. Our research questions, assessment instruments and curriculum continue to evolve. There will be a continuing effort to run similar projects for primary and secondary school students. This effort needs to be strengthened by professional development of teachers and a unit on engineering education added into teacher education programmes. Sustainable courseware can only exist with teacher support.

References

Bradley, D., Noonan, P., Nugent, H., & Scales, B. (2008). Review of Australian Higher Education Report: Final Report. (E. a. W. R. Department of Education, Trans.).

Creswell, J. W. (2003). *Research design: Qualitative, quantitative and mixed methods approaches.* Thousand Oaks, CA: Sage Publications, Inc.

Cronbach, D. J. (1951). coefficient alpha and internal structure of tests. Psychometrika, *16*(3), 297-334.

Cunningham, C.M & Hester, K. (2007). Engineering is elementary: An engineering and technology curriculum for children. *114th American Society for Engineering Education Annual Conference.* Honolulu, HI.

Denzin, N. K., & Lincoln, Y. S. (1994). Introduction: Entering the field of qualitative research. In N. K. Denzin & Y. S. Lincoln (Eds.), *Handbook of qualitative research* (pp. 1-18). Thousand Oaks, CA: Sage.

Fraser, B.J. (2007). Classroom learning environments. In S.K. Abell & N.G. Lederman (Eds.), *Handbook of research on science education* (pp. 103-124). Mahwah, NJ: Lawrence Erlbaurm Associated.

Goodrum, D., & Rennie, L. J. (2007). *Australian School Science Education National Action Plan 2008 – 2012*. Retrieved from http://www.dest.gov.au/NR/rdonlyres/94684C4C-7997-4970-ACAC-5E46F87118D3/18317/Volume1final_28August2008.pdf.

Lachapelle, C.P. & Cunningham, C.M. (2007). Engineering is elementary: Children's changing understanding of science and engineering. *114th American Society for Engineering Education Annual Conference.* Honolulu, HI.

Lewin, K. (1936). *Principles of topological psychology.* New York:McGraw.

MCEETYA (2006). *Statements of learning for science.* Accessed at http://www.science.org/au/primaryconnections/curriculum-resources/.

Pearce, A., K. Flavell, et al. (2010) Scoping Our Future: Addressing Australia's Engineering Skills Shortage. http://www.anet.org.au/wp-content/uploads/2010/12/Scoping-our-futureWEB.pdf

Stern, G.G. (1970). *People in context: Measuring person-environment congruence in education and industry.* New York:Wiley.

Taylor, P. (2008). *Fixing Australia's engineering skills shortage is an urgent and shared responsibility, Engineers Australia media release, 29th January*. Retrieved from http://www.engineersaustralia.org.au/da/index/getfile/id/5792

Walberg, H.J. (1981). A psychological theory of educational productivity. In F. Farley & N.J. Gordon (Eds.), *Psychology and education: The state of the union* (pp. 81-108). Barkley, CA: McCutchan.

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