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Invited Paper - Preparing the Global Engineer: How learning to teach in a Service-Learning Project Develops Effective Communication Skills in Engineering Students

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Robyne Bowering began lecturing in science teacher education at Monash University in 1991. In 2006 she became the Schools' Technology Project Coordinator. The Project operates as a partnership between the Faculties of Engineering and Education and has been specifically developed to enhance the professional skill competencies of final year engineering students through their placement in schools, where they design and teach a STEM-based unit of work. Robyne's pedagogical focus is on providing the best learning environment for individual student growth and her current research interest is how learning to teach provides engineering students with the cognitive, conative and metacognitive skills needed for effective problem-solving in the engineering workplace.

Preparing the Global Engineer: How learning to teach in a Service-Learning Project Develops Effective Oral Communication Skills in Engineering Students.

Abstract

Globalisation, mass migration, the digital revolution and a growing need for environmental stewardship are changing the way goods and services are designed, produced, distributed, consumed and disposed of. To be able to work successfully, both domestically and globally, engineers need the capacity to understand changing contexts, constraints and cultures and have the capability and drive to work with people who define and solve problems differently. As the engineering workplace evolves, there are increasing demands from industry for engineering faculties to produce student graduates who are technically able and possess proficient professional skills. Monash University's Schools' Technology Project has been specifically designed to develop a range of professional skills in their final-year engineering students. The project is a service-learning program placing students into schools to design and teach STEM-based (Science, Technology, Engineering and Mathematics) units of work. This paper is a phenomenological description of how the experiential learning opportunities provided during the project enhance one aspect of student professional skill development: effective oral communication.

Introduction

'Engineers are hired, retained and rewarded for solving problems'[1]. Globalization, mass migration, the digital revolution and a growing need for environmental stewardship are creating new contexts and new types of problems for engineers to solve.[2] To be successful in the rapidly changing world, engineers need to be globally competent and locally relevant. Downey et al.[3] define global competent engineers as those who possess 'the knowledge, ability, and predisposition to work effectively with people who define problems differently than they do.' Engineering has become a discipline where the social and technical have become inextricably intertwined.[4] Engineers need to be technically able and proficient at managing relationships and building networks. They need strong social skills (a sub set of professional skills/soft skills/generic skills/transferable skills) in particular:

- effective oral communication skills - able to differentiate and cater to different audiences.[2, 5] They need to be able to communicate efficiently in English, the official international language of business and the sciences.[6] They need to be purposeful when delivering information and instructions, and competent at interpreting information – verbal, non-verbal, written, visual and electronic;[7]
- cogent interpersonal skills – enthusiastic, collaborative workers who are open-minded and aware of their own perspectives and assumptions, and those of others.[2] They need to have cultural awareness, not just in terms of different ethnicities, but also the culture of organisations.[8]

Earl Dowell, Dean of Engineering at Duke University stated "…engineers who are adept at communications have a considerable advantage over those who are not..."[9] Effective technical and non-technical communication, as a two-way process, is paramount to an engineer's success. Yet the emphasis on developing communication skills in many engineering courses is limited to the one-way delivery of discipline-specific information through technical writing and the occasional oral presentation, supported by text and images on a screen. Oral communication in the broadest context is a learnable skill.[5] Despite this, studies from around the world reveal that it is the competency most frequently reported as being deficient in the engineering workplace. [6-8, 10]

Oral communication, like many skills identified by employers as insufficiently developed in graduates, can be enhanced through improved faculty teaching and learning methods. The new curricula should encourage deeper learning and understanding of context. They should contain among other things: integrated experiential activities, interdisciplinary perspectives, addressing different learning styles and helping students to develop life-long learning skills by assisting them to understand how they learn and provide a connectedness to the needs and issues of the broader community.[11-13]

Service-learning is a pedagogical practice that deliberately integrates community service activities with educational objectives. Students engage in meaningful learning through applied, active, project-based learning, drawing on multiple knowledge sources (academic and community knowledge, student knowledge and experience,).[14] They use what they learn in the classroom to solve real-life problems. They not only learn the practical applications of their studies, they become actively contributing citizens and community members through the service they perform.[15]

Trevelyan advocates that '… many aspects of engineering practice are closely related to teaching, particularly technical coordination and training. This creates an interesting opportunity to improve engineering education. If students learn effective teaching skills, first they will acquire social skills that will enable them to be more effective engineers, second they will learn the 'real technical stuff' better ...'[16]

This paper provides a brief overview of oral communication practice in the engineering workplace. It looks at the awareness that final-year engineering students have of the value that employers place on effective oral communication skills and then demonstrates how the Schools' Technology Project provides opportunities for engineering students to practise and refine their oral communication skills in a range of contexts with different audiences.

The role of oral communication in engineering practice

Studies suggest that engineers spend around 60% of their working day interacting with people. The majority of this interaction is orally based communication: informal face to face, on site, in meetings, in training sessions, over the phone, etc.[4] Darling and Dannels' 'Report on the Role of Oral Communication in the Workplace'[10] indicated that practising engineers deemed message construction (being concise, clear and logical) to be the most important oral communication skill to have in the workplace. Interaction with others was a close second (interpersonal skills, teamwork, negotiation, asking and answering questions), followed by public speaking skills and delivery (confidence, preparation, etc.).

Trevelyan[17] reports that young engineers spend more time listening than talking during conversations, while Lee[18] suggests that the work performance of novice engineers can often be predicted by the quality of the social relationships they form with 'expert' engineers, and their willingness to ask for and accept guidance.

What is the Schools' Technology Project?

The Schools' Technology Project (STP) is a semester-long, service-learning elective, open to fourth Year students from all engineering disciplines at Monash University's Clayton Campus. The Project operates as a partnership between the Faculties of Engineering and Education and local elementary and high schools. It is one of two engineering units

recognised in the Monash Passport: Act Program, a University-wide framework, 'providing students with the opportunity to develop a range of skills and abilities, through community engagement, work-integrated learning activities and peer-to-peer learning, that not only serve as a foundation for career development, but can also be applied to transform local and international communities'.[19]

At the start of the semester, the STP students participate in a series of workshops on: understanding how we construct and retain knowledge, different learning styles, effective communication and presentation skills, motivation, goal setting, lesson planning, leadership and reflection. They are then placed into a suitably matched school to plan, organise and teach a STEM-based unit of work. The STP students specifically design their unit of work (project) around the brief given to them by their supervising teacher and the interests and capabilities of the children that they work with. The projects are typically 12+ hours long and are delivered over six weeks. Two or more STP students, preferably from different engineering disciplines, are placed at the same school; they work with the same grade level of students, on the same topic but with different classes. This enables the students to plan their classes and reflect on their learning with a colleague.

For the schools involved in the Project, the engineering students bring to the classroom novel, authentic learning experiences and an understanding of the work of engineers. Peter Hall, Victorian Minister for the Teaching Profession, described the project as '…not only brilliant because of the unique learning experience it creates for students, but it doubles as hands-on professional development for teachers. The Schools' Technology Project inspires not only the students, but the teachers themselves. They see how hands-on, inquiry-based learning activities can energise theoretical concepts and in turn motivate and excite students'.[20]

The school placement provides the STP students with a supportive, professional workplace, where they are encouraged to step outside their comfort zone, in order to develop a wide range of professional skills.

"*The STP has been one of the most rewarding units I have taken during my time at University. The various teaching sessions have put me into situations where I can learn and improve on my soft skills in real-life situations, which is much better than learning purely based on theory. It also allowed me freedom to fail, learn from my mistakes and practise what I have learnt effectively.*" (Andrew)

Since its inception in 1991, nearly 1300 engineering students and over 30000 elementary and high school students (and their teachers) have benefitted from their involvement in the Project.

Setting the context for the need to develop effective oral communication skills

In the first week of the elective the students complete an assessment task requiring them to:

1. Look at the student competency outcomes outlined by the following engineering program accrediting agencies: Engineers' Australia, ABET, Inc. and EUR-ACE®, and at the CDIO Syllabus to get a feel for the engineering competencies that are considered to be important around the world.
2. Conduct an informal audit of their personal professional skills.
3. Analyse and respond to Nair et al.'s 'Re-engineering graduate skills - a case study'.[21] A study of the 2007 Monash University survey of employers' satisfaction levels of their Engineering graduates. The students are reassured that the findings are typical for similar surveys conducted throughout the world, and certainly not unique to Monash or Engineering. In their response, the students need to state whether they

agree or disagree or are surprised with the survey findings and back up their statements with relevant examples from their studies or work experience.

4. Identify three professional skills that they will specifically work on developing during the semester and the measures they propose using to evaluate how successful they are in meeting their goals.

Analysis of the student responses from 2010 to 2012 (322 students) indicated that nearly half (48%) of the students were unaware of the value that employers placed on professional skills. Most assumed that their technical skills, based on their subject selections and results at University, would be more than adequate for them to secure and thrive in their first engineering job.

"*I was under the impression that the best person for the job was always the person who was the most technically able, this article has broadened my understanding of the credentials that are required by employers.*" (David)

Eleven per cent of the students were indignant at the findings, convinced that they possessed more than adequate professional skill levels. Unfortunately, these students tended to have a limited understanding of the range and context in which many of the skills are used the workplace. For example, two students attached a copy of a mark sheet their group had received for an oral presentation in another subject, whose opening comment was 'Your presentation was better than 99% of the presentations I see at conferences'. From my experience, this is not necessarily the highest bench-mark to assess effective presentation standards by and this one comment led the students to believe that they had outstanding oral communication skills.

A total of 4% of students were complacent about the findings.

"*Engineers around the world are hired for their technical skills and problem-solving abilities. They are not known for their communication skills and people skills.*" (William)

The remaining 37% of students were not surprised by the important role that proficient professional skills play in the workplace; interestingly, most of these students were already working part-time in industry.

Two thirds (68%) of the students believed that Universities need to be more proactive in addressing industry concerns, or at least alerting their students to the concerns.

"*The issue is best addressed with a complete restructure of HOW subjects are taught and assessed, rather than WHAT is taught...apart from group projects, the engineering course is primarily just counter-productive solo work and self-reliant study.*" (Peter)

A number of students lamented that a lack of lecturers with competent social skills was probably a contributing factor to them not placing much value on developing their own skills.

"*Most lecturers are dry, have terrible communication skills, and form no personal one-on-one relationships with students. There is never any attempt to make learning interesting, relevant or fun.*" (James)

The two most frequently selected professional skill goals set by students enrolled in the STP over the past 3 years have been improving oral communication (66% of students) and developing interpersonal skills with colleagues and clients (28%). This formative assessment task explicitly informs the students that developing their professional skills is an integral part of their engineering education. Allowing the students to identify and choose the professional skills they most need to work on gives them ownership and responsibility and is a powerful motivating tool.

How the placement provides authentic contexts for oral communication development

Understanding the client's problem and perspectives to define the project: The ability to accurately deconstruct ill-defined problems and interpret the client's desired explicit and implicit project outcomes is vital to the overall success of a project. The client's whole project experience impacts on the professional reputation of those directly involved in the negotiation process and their employer.

The week before the STP teaching placements begin, a briefing meeting is held between the STP students working at the same school and their supervising teachers (the client). The STP coordinator attends each meeting as facilitator and mentor. The main purpose of the meeting is to negotiate the commitments (days/times when the STP students will teach, teacher expectations, e.g. lesson plans will be emailed through two days before each session; and Monash and student expectations, e.g. the type of feedback required) and to establish the broader aims and learning objectives of the project (e.g. hands-on, problem-based learning, with an emphasis on fair testing and team-work). The meeting also provides an opportunity for the STP students to begin building a rapport and trust with their client.

The teachers come to the meeting knowing the big-picture learning outcomes they want for their students, but don't know how to achieve them authentically using engineering knowledge and skills (Engineering as a subject, is not officially included the Australian School Curriculum). To ensure that their first meeting with the client is productive, the STP students need to have conducted some preliminary research and bring relevant suggestions and ideas to the discussion table. The STP students learn that the effort they put into preparing for the meeting not only provides them with the confidence to 'sell' their ideas, but also provides a tangible structure for the discussion and a guide to the types of questions they need to ask their client e.g. can we conduct parts of our lessons outside? Do any students have special needs that we should accommodate in our planning?

"*We knew that our teachers were keen for the Grade 5 classes to work in small teams on a design/construction project. We were keen to work on a project that we thought the children would find exciting and would use information from both of our backgrounds - civil and materials engineering. Designing and building trebuchets that could launch a tennis ball across the school oval, sounded like a great idea. Dave and I took the liberty of attending our first meeting with a draft of our proposed lessons, a prototype of a simple trebuchet that could be built by the students and a You-tube clip, showing trebuchets in action. The teachers loved the idea and were impressed with our initiative.*" (Simon)

At the conclusion of the briefing meeting, the STP students spend at least one hour observing their client teaching the children that they will work with. They are provided with a list of teacher and student behaviours to pay attention to. For example: how did the teacher give out instructions; were they written, verbal, demonstrated or a combination? Were they repeated more than once? Were they 'chunked'[22] into bundles? What non-verbal communication occurred? How did the children respond? Guided observation[23] plays an important role in the STP students seeing that effective communication is often more about how a message is delivered rather than what the message is.[24] The observation session provides the students with the opportunity to see how their learning from the STP workshops translates into the classroom. The modelling of effective communication and interpersonal skills by the teacher provides the STP students with a concrete experience to reflect on and consider using when they start teaching.[25]

At the conclusion of the observation session, the engineering students spend 10-15 minutes introducing themselves to the children, explaining what engineering is, what they are going to

be teaching over the next few weeks and discovering what in particular the children might like to find out about or do during the project sessions. This short introduction to standing up and talking in front of a relatively large group on a topic that they know more about than anyone else in the room, provides the STP students with a much-needed confidence boost. It also gives them some insight into the prior knowledge and interests of the children they will work with. The initial visit to the school provides the STP students with some understanding of the culture of the school. They get a feel for the types of relationships that exist between teachers and their students, the type of learning that occurs in the classrooms (student-centred or teacher-centred, prescriptive or exploratory, intrinsically or extrinsically motivated) and the protocols around being a visitor to the school. The quicker the STP students can fit in with the accepted norms, the more enjoyable their placement is for them, their client and the children.

Before the engineering students officially begin planning the scope and sequence for their project, they meet with the STP coordinator to clarify their understanding of their client's objectives for the project. This meeting provides the STP students with a timely reminder of the importance of listening to their client and keeping their client's perspective of the project's outcomes at the forefront of their thinking. For many of the STP students, their focus for the project has become centred on what the children will do, rather than what the children will learn as a result of doing…

The importance of purpose and learning the skills of collaboration: Effective oral communicators in the classroom, the boardroom or on site speak with a purpose. They know upfront whether they want to convince, inform, identify a problem or open up a discussion and they structure their conversations and presentations accordingly.

To be successful in their teaching, the STP students need to visualise the 'big picture' of their project first, so that they can plan and structure the individual lessons appropriately. To see their project as a whole and to begin the process of collaboration, students working at the same school (planning team) work together to construct one concept map[26] containing all the key ideas, terms and activities that could be included in the project. As they create links on the map, groupings of like information and activities form helping the students to identify individual lessons, and they begin to recognise which ideas are critical to meet the project's objectives versus those that are 'nice to know but not necessary' and where contingencies need to be considered. The process of forming the project's overall structure brings out interesting interdisciplinary discussions can reveal misconceptions in individuals' understandings.

Most teams then make the decision to split the planning for the individual lessons between them. The sharing of the responsibility for developing lesson plans often brings a more sophisticated level of team-work than is typically seen in other student group projects. They can't simply rely on the 'divide and conquer' approach to doing a group assignment, as all members of the team ultimately need to take ownership of each lesson plan as they will be solely responsible for understanding and delivering all the content, organising the activities and answering questions once they begin working in their separate classrooms. When the students meet again to share their plans, it is done critically and collaboratively. Every member of the team needs to leave the meeting with more than just the physical plans and PowerPoint presentation of 'what' will be done 'when' and by 'whom'. They also need a clear understanding of 'why' specific components have been included in that particular sequence, excluded or modified and be aware of 'how' to introduce/demonstrate an idea or

run an activity so the children will learn how to apply, analyse, evaluate or create. Having a clear understanding of the purpose of each lesson component increases the chance that the messages delivered in the classroom are valid, logical, concise and clear, and gives the STP student the confidence to deliver the lesson and the flexibility to appropriately change components of the lesson on the spot if necessary.

"*Being an international student, I have had a lot of self-doubts especially when it comes to communicating with people from different language and culture backgrounds. The school placement had given me a huge confident boost as it made me realize that I could actually communicate efficiently and it was my lack of knowing how to prepare and lack of confidence in my head all along that was preventing me from doing it.*" (Jacky)

Knowing and catering to your audience: Effective communication is measured by the quality of the message that is received and understood rather than by the quality of the message that is delivered.[27] If we want to be effective communicators, we must be prepared to connect with our audience and adapt to their needs.

The STP students are encouraged to use BSCS's 5E Instructional Model[28] for their lesson planning. This approach uses Engage, Explore, Explain, Elaborate and Evaluate phases to identify the prior knowledge of the children in their classes and creates the interest/ motivation for them to want to know more. The different phases provide relevant opportunities for the children to investigate and question new ideas, language and concepts until they can comfortably scaffold the new knowledge onto their existing knowledge and are able to own and apply it. The Explore phase is particularly useful for connecting with audiences with a non-technical background or a language background different to the presenter, as the audience can learn the basics in their language, which can later be translated into the appropriate jargon during the Explain' phase.

"*This week I learnt my second lesson of teaching… There is no such thing as a concept too difficult for a student to grasp – the key is teaching in a way that students can understand.*" (Hoon)

The 5E model also encourages instructors to design learning environments that are accessible to audiences with a variety of different learning styles and preferences. The STP students are introduced to, and complete an assessment task on, two learning style theories, Felder-Silverman's Index of Learning Styles[29] and Fleming's VARK[30], in the workshops that run before the school placement. In their lesson planning, they are expected to consider the learning style preferences of the children they teach so that they include the appropriate means (analogies, associations, demonstrations, models, small group discussion etc.) and methods (verbal and non-verbal communication, timing of questions and thinking etc.) of communication to ensure the successful understanding of instructions/, ideas and concepts.

One of the advantages of the STP students working with children is that children are not embarrassed to say that they don't understand the idea being explained and will quite happily ask for the same concept to be re-explained multiple times. Explaining the idea the same way, using the same example each time does not help. The STP students quickly learn that as part of their planning for effective communication, they need to think of multiple ways of explaining the same idea and consider what types of examples would be most appropriate for their audience.

"*Before STP, I wasn't aware of the different learning and communication styles and often found myself frustrated and annoyed when people didn't get ideas that I found easy and straight forward. Understanding the different styles means that I can now change the way I explain things so that more will understand what I am trying to say. This will definitely benefit me when I transition into the workplace, and will give me an edge in communication.*" (Ellen)

Oral communication during the placement: The teaching placement provides the STP students with the opportunity to practise effective two-way communication in a variety of contexts with multiple audience types, requiring them to adjust their style accordingly. They talk with their client to establish and clarify expectations, to discuss and negotiate ideas, to establish a rapport and trust and to seek and respond to constructive feedback. They explain their project to the School Principal and what learning they are gaining from the experience. They communicate with a large group of children to engage, inform and convince them, to explain technical concepts, give instructions and demonstrate how to do things. They work with small groups of children to motivate them, build team work, identify problems, resolve conflict and discuss and consolidate ideas, and work with individuals to understand their thinking and answer their questions. They collaborate with their peers to exchange ideas, create resources and solve problems and they talk with their mentor (STP coordinator) about their progress, concerns and learning and to organise the loan and use of equipment. While there is a considerable emphasis on teaching children and working with the constraints and culture of a school during their placement, the students are also required to reflect on lessons learnt in the classroom and how they will be able to transfer their new learning into the workplace.

The role of feedback and reflection: The opportunity to teach a lesson, receive immediate constructive feedback and reflect on what worked and why, and what didn't work and why with their teacher, colleagues and STP coordinator before planning the next lesson plays an important role in developing student capacity and confidence. Feeling comfortable about asking for guidance and strategies empowers the students to try new means and methods of communication and grow as a result.

"*I have learnt that asking for help appropriately is a sign of strength, not a sign of weakness.*" (Andrew)

Conclusion

Students learn best when they are active participants in their own learning, when their learning is purposeful and challenging and they are provided with opportunities to apply their new understandings to authentic tasks. Students need to be able to evaluate their own learning and see opportunities to apply it to new contexts.

The Schools' Technology Project provides engineering students with a comprehensive approach to enhancing their oral communication skills required for global competence. The students understand up front the value that accrediting bodies and employers place on effective communication skills, providing the motivation for knowledge, skill and attitude development throughout the elective. The students are active participants in their learning and their communication of knowledge and collaborations with others are authentic.

The school placement provides a supportive, professional environment for the engineering students to practise and refine their oral communication skills. Schools are places where effective two-way communication is the focus, and where planning for effective communication, having a purpose, knowing one's audience and reflecting on learning is paramount. Schools are places of multiple perspectives and personalities, where there is never one right way for communication to occur. They are places of learning, where stepping outside comfort zones is encouraged and mistakes made are viewed as opportunities for learning and growth. Teachers have the expertise to guide and give constructive feedback and children are the barometers of communication success.

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