Enhancing Technical Writing Skills for Undergraduate Engineering Students

Beverly Coulter, Roslyn Petelin, Justine Gannon, Kate O'Brien, and Corrie Macdonald

University of Queensland School of Chemical Engineering, University of Queensland School of Communication and Arts, University of Queensland School of Communication and Arts, University of Queensland School of Chemical Engineering, University of Queensland School of Communication and Arts

Corresponding Author Email: b.coulter@uq.edu.au

Context

Effective technical writing is an essential skill for professional engineers. Graduate engineers spend 30–40% of their day writing, and professional engineering organisations consistently list communication as a key graduate competency. At the same time, technical writing is one of the least developed technical skills in engineering undergraduate programs. This paper discusses the initiatives and outcomes of a pilot program in the School of Chemical Engineering at The University of Queensland (UQ) designed to enhance the technical writing skills of engineering students.

Purpose

The aim of this pilot study is to enhance the technical writing skills of engineering students by embedding an integrated and progressive technical writing program in core undergraduate engineering courses.

Approach

In this pilot study, a multi-disciplinary team comprising academics from the School of Chemical Engineering and the School of Communication and Arts at UQ collaborated to develop, deliver, and evaluate a series of new writing lectures and workshops embedded in core chemical engineering courses. The content of these materials was informed by a literature review of best practice in engineering writing programs, a survey of Australian industry, and a curation of e-resources including the UQ Massive Open Online Course (MOOC) on writing and grammar.

Results

Early results from the pilot program are promising. We found that most students valued the technical writing support and they were able to incorporate feedback from teachers to improve the quality of their written assessments. The pilot study also highlighted the challenges of implementing program-wide changes to the established curriculum, including engaging students' attention in technical writing workshops and obtaining the support of other academics.

Conclusions

Early results from this work show that is possible to enhance the writing skills of undergraduate engineering students by embedding active learning activities in their core engineering courses. Future work in this project will investigate how to expand the reach of technical writing activities across the School of Chemical Engineering and across the Engineering Faculty.

Keywords

Technical writing, engineering education

Introduction

Effective technical writing is an essential skill for professional engineers. Most engineers spend a significant part of their day writing (Trevelyan & Tilli, 2008) and engineers who write well are more likely to be promoted (American Society of Mechanical Engineers, 2011). In the report *Visions of Engineering in the New Century: The engineer of 2020* (2004), the National Academy of Engineering states: “As always, good engineering will require good communication”.

Many Australian-based engineering companies regard communication skills as increasingly important because of increased specialisation and the trend towards global outsourcing of engineering functions (Beer & McMurrey, 2014; University of Adelaide, 2009).

For these reasons, engineering educators have a responsibility to ensure that students learn writing skills alongside the technical skills of their discipline. Entry-level employees and graduates will face a constant and complex array of writing tasks, so they need to be able to confidently articulate technical ideas in compelling, logical, coherent, and economical prose (Petelin, 2016).

In Australia, the integration of writing skills into engineering curriculums is recognized as important, but rare in practice (McGregor et al., 2000). With both limited resources and limited scope to expand the content taught in existing engineering courses, we set out to obtain evidence about the current state of graduate writing skills, how these skills are meeting industry expectations, and what opportunities exist to enhance the competence, employability, and reputation of engineering students

To this end, a multi-disciplinary team comprising academics from the Schools of Chemical Engineering and Communication and Arts undertook a pilot project to embed technical writing into existing core courses. The key deliverable of the project to date has been a set of technical writing lectures and active-learning tutorial activities designed around best practice in teaching technical writing in engineering faculties, the perspective of Australian industry, and elements of WRITE101x English Grammar and Style, a MOOC (massive open online course) on writing and grammar.

The project was funded by a Strategic Teaching and Learning grant offered by the UQ Faculty of Engineering, Architecture and Information Technology (EAIT).

This paper discusses the methods and early findings of this pilot project of the School of Chemical Engineering at The University of Queensland.

Review of the literature

Industry views

There have been calls to embed writing instruction into engineering courses in Australian universities for more than 20 years. In 1996, the Institution of Engineers Australia (IEAust, now Engineers Australia) commissioned a national review of engineering education, which ultimately resulted in new standards that included “effective oral and written communication” as one of 10 generic competencies required by a “professional engineer graduate” (Engineers Australia, 2013).

Recent surveys show that Australian employers still identify written and oral communication skills as a critical competency when recruiting engineering graduates. One 2013 survey found that communication skills were the criterion most important to these employers (Graduate Careers Australia, 2014).

Similarly, recent studies commissioned by professional engineering bodies confirmed that skills in written and oral communication and in creative and critical thinking (sometimes referred to as ‘soft skills’) are necessary to be a competent engineer, but were not being

adequately taught in engineering degrees (Lattuca et al. 2006; Lee 2003). In response, industry professional bodies have developed new standards reflecting the skills required by what Ardington (2011) has called the 'three-dimensional' engineer.

Technical–writing education frameworks

Engineering educators have adopted (and adapted) various frameworks drawn from writing pedagogy and other areas of educational theory. Writing in 1995, Robinson and Blair note that frameworks for teaching writing can be grouped into three main categories:

- writer-oriented composition ("the concentration on the process of writing, including prewriting activities, drafting, editing and rewriting")
- genre-oriented composition ("analysing examples of good and bad texts [from a particular genre] and incorporating the good features into one's own writing")
- reader-oriented composition ("the writer must know, understand and write for the reader").

Our pilot project has used elements of all three frameworks.

The University of Adelaide, which integrates the teaching of writing and teamwork skills throughout its engineering degree, adopts a "democratic and student-centred approach" (Missingham & Matthews, 2014). Yalvac et al. (2007) concur, endorsing instruction that is "learner-centred" and "community-centred". The University of Adelaide also uses what it calls a "spiral curriculum", based on the work of Jerome Bruner, who argued that a curriculum "should revisit the basic ideas repeatedly, building successively until the student has grasped the full formal apparatus that goes with them" (1960). We understand the value of a spiral curriculum and have implemented follow-up sessions on writing in our project.

We have also taken on board a critical thinking framework. As Bean says, "writing is both a process of doing critical thinking and a product communicating the results of critical thinking" (Bean 2001, quoted in Damron & High 2008). Damron and High (2008) use "a model of critical thinking to structure writing assignments" for first-year engineering students.

Yalvac et al. (2007) also apply a critical thinking framework to teach writing to later-year engineering students, seeking to improve "student performance in difficult writing skills such as argumentation and synthesis". Critical thinking and effective writing are closely intertwined. We recognised in our lectures and workshops that understanding and practising critical thinking is crucial to the process of effective writing.

Different writing skills—generic, academic, and discipline-specific

Generic writing skills are writing competencies that are useful to any writer in any situation. These generic skills include mechanical aspects of writing such as spelling, punctuation, and grammar (Ardington, 2011; Fernandes, 2012; Lord, 2013), but also higher-order skills such as writing clearly and concisely, structuring paragraphs and documents in a logical fashion, and formulating persuasive arguments (Manion & Adams, 2005; Robinson & Blair, 1995).

Academic writing skills are those required to successfully write academic assignments (such as essays). Learning the conventions of academic writing presents one of the greatest challenges for many first-year university students, including many engineering students (Horstmanshof & Brownie, 2013; Skinner & Mort, 2009; Wilkes et al., 2015; Wischgoll, 2016).

Academic writing skills include approaches to content and structure that reflect the expectations of an academic audience (Wischgoll, 2016). Library research and referencing are also key (Horstmanshof & Brownie, 2013). But, to be a competent academic writer, students must also be able to construct a convincing argument and understand the context in which they are writing.

Discipline-specific writing skills in this case are those required by engineers. To acquire these skills, students need to know the different types of documents written by professional engineers; understand the purpose, content, and structure of those documents; and practise writing them (Boyd & Hassett, 2000; Felder & Brent, 2003; Robinson & Blair, 1995; Trevelyan, 2010). They include technical memos, reports, proposals, and specifications.

In addition, students must learn the writing *style* used in engineering documents. Walker (1999) refers to the "engineering persona", and argues that it is linked to stylistic choices such as when to use the passive voice and how much to explain key terms and concepts. Only by using such stylistic features appropriately, she says, will students convey an "experienced engineering persona, one that will be accepted". This is essential if graduates are to meet professional expectations and fit in with their peers when they join the workforce.

Best practice for teaching writing skills to engineering students

The literature concludes that the best way to embed writing within an engineering course is to base it around problem-solving projects directly relevant to engineering problems (rather than teaching 'theoretical' writing skills). This approach allows students to apply and integrate knowledge and techniques learned across their course to a realistic problem, developing creative skills, formulating problem statements and specifications, solving open-ended problems, considering alternative solutions, determining feasibility considerations, and evaluating realistic constraints. Using assignments that include problem-solving provides an opportunity to show how solutions to problems should be presented as fully developed and carefully written reports, not as lists of calculations. Allocating marks for the writing component within assignments will also help ensure students engage with the material and see it as 'need to know' for their academic success.

Best practice in assessing and giving feedback on students' writing (which we have followed) advocates the following:

- Writing assignments should relate to course content and resemble the writing done by professional engineers.
- However, personal 'reflective' writing assignments also benefit students.
- Shorter writing assignments benefit both students and staff.
- Effective and timely feedback on writing tasks is critical to improving students' writing skills.
- Engineering staff should receive training in how to provide effective feedback on writing.
- Good rubrics are important, and teaching to a rubric can deliver good results.

Methodology

The key initiatives of this pilot project included:

- conducting a literature review to identify best practice in the teaching of technical writing to undergraduate engineering students
- surveying Australian engineering employers to obtain more evidence about where employers feel new graduate writing skills are lacking
- developing and delivering technical writing materials for core, compulsory courses
- evaluating the benefits of the program through ongoing student feedback.

Industry survey

We distributed an online survey to 55 Australian engineering employers from around Australia in September 2016. The companies were asked a series of questions relating to how valuable these employers regard writing ability when employing graduate engineers.

Twenty-nine survey responses were received. Of these respondents, 60% worked in a large engineering consulting firm with more than 100 employees, 28% in a smaller firm of fewer than 100 employees. The remainder of the respondents were from state government, local government, and academia. Within these organisations, 39% of respondents were in a management position and 46% were in a technical position. 71% of respondents had supervised UQ engineering graduates.

Our industry survey confirmed that effective writing skills are highly valued by engineering employers in Australia. As a broad summary:

- 88% of respondents view technical writing skills of graduate engineers as either vital (60%) or important (28%).
- 58% see the primary importance of writing training as the reduced need for multiple revisions of works.
- 85% of respondents fully support integrating writing components into the engineering curriculum.

Respondents were asked to nominate the top five writing-specific issues that make documents in their organisation difficult or frustrating to read. The major issues highlighted were:

- inability to highlight or identify critical information
- lack of clarity
- wordiness
- inability to summarise
- weak connections between words and data
- poor organisation
- incorrect grammar and convoluted syntax.

Respondents made the following comments about the writing skills of engineering graduates in particular:

- Verbose and indirect writing is very common among graduates.
- Graduates need to develop skills in writing in a range of engineering formats including emails, letters and memos, progress reports, summaries, and PowerPoint slides
- Interpretation of technical data and succinct summaries are key needs for graduates.

Approximately 33% of respondents offer in-house writing training to their staff, 25% employ external consultants to deliver writing training, and 8% use Engineers Australia's writing training courses. 55% would still offer in-house writing training to staff even if writing is incorporated into the engineering curriculum.

> *In general, engineers are not able to submit technical information directly to clients until they are at a senior level about five years after graduation. (survey respondent)*
>
> *Writing skills and good project management skills go hand-in-hand. This is important because it shows systematic thinking about a project. Systematic thinking and good technical writing cannot be separated. (survey respondent)*

Delivery of lectures and workshops

The key aims of this pilot writing program were to raise student awareness of the importance of writing clearly and to explain the elements of effective technical writing, including conciseness, clarity, accuracy, relevance, and significance. To achieve these aims, and armed with the knowledge gained from the literature review and industry survey, we developed a range of technical writing instructional material specifically designed for the chemical engineering students.

During 2016–2017, this material was delivered to the students in a number of different formats including:

- A one-hour lecture to 200 students in the core second-year, introductory chemical engineering course (CHEE2001 Process Principles). The purpose of the lecture was to highlight the importance of effective writing and to introduce the elements of good writing including knowing your audience, structuring technical reports, writing clear paragraphs, and using plain English.
- A two-hour active-learning workshop for 200 students in CHEE2001. In the workshops, students worked through a series of activities in pairs and groups to practise the writing principles outlined in the lecture. The cohort was divided into two groups of 100 students to allow for more manageable classroom interactions.
- A two-hour active learning workshop for 180 students in the third-year, core chemical engineering course (CHEE3004 Unit Operations), which reinforced and extended the messages of clear writing to include simple sentence construction, pitfalls of nominalisation, the use of the active voice, and simple word selection. Once again, the cohort was divided.
- In-class and written feedback from CHEE2001 was provided by academic staff on the quality of the students' executive summaries for the first of two project technical reports.
- A bank of accessible writing resources was provided for the students via the course Blackboard sites, including a guide to writing a technical report, examples of good executive summaries, and recommended texts on technical writing.

Findings

Writing lectures and workshops

The pilot study produced three main findings. Firstly, we found that most students do value technical writing support and can improve their writing skills with direct writing tuition, teacher feedback, and access to relevant writing references. Secondly, the collaboration of academic staff from different disciplines across the university was effective in developing and delivering useful writing resources for our students. Finally, it was clear that persistence and creativity are required to engage students and staff in program-wide changes to the established curriculum for non-core activities. In the following section, we elaborate on these findings and provide some examples of our students' responses.

Students value writing support and do respond to tuition

The need for, and value of, technical writing support for our undergraduate chemical engineering students is clear. Evidence includes:

- Many of the students' written assessment submissions, especially those in the early years of the degree, are not at an acceptable, industry-ready standard. Common issues with students' reports include poor overall structure, convoluted sentence

construction, poor structuring of argument, buried findings and recommendations, and poor regard for the audience of the report.

- Students themselves reflect that that they feel daunted by the prospect of writing technical reports. During a writing workshop, we asked the students to reflect on how they felt when they sat down to write for their university assessment. The responses were uniformly negative, with typical responses of ‘upset’, ‘lethargic’, ‘sad’, and ‘depressed’.

Most students appreciated the writing support that they received. When we surveyed the CHEE2001 students after the writing workshops in 2016 and 2017, >80% said that they found value in the lecture and workshops, >90% said that they had implemented some of the new learnings when writing their assessment pieces, and >90% said that they would like to see more technical writing support in other chemical engineering courses. At the same time, we observed a noticeable improvement in the quality of the CHEE2001 reports in the cohorts to which we gave writing instruction and feedback.

Some examples of students’ responses to the writing components were as follows:

> *I know of other students that might not take it as seriously as the actual content of the course, but knowing how to write reports is something I consider to be important. I used to think bigger words, longer sentences = smarter, but I've learned a lot about how to improve my writing.*
>
> *I would like to really perfect the executive summaries I write. From the feedback I got from my executive summary for Project 1, I seem to be in a position where I am close to being able to consistently write clear, concise and informative summaries of the report.*

Value of cross-discipline collaboration

Every discipline has its own system for looking at and organising experience—a perspective on the world that is reflected in its questions, research methods, and the roles its practitioners play. Writing in every discipline is a form of social behaviour in that discipline, so students need to be socialised into the intellectual conventions of their disciplinary and professional discourse communities (Petelin, 2012).

Our working party consisted of academic staff from two UQ Schools, the School of Chemical Engineering and the School of Communication and Arts. Over the course of the last two years, we met regularly and collaborated to develop and deliver writing tuition specifically tailored for chemical engineering students. We each brought to the team different knowledge and perspectives based on our disciplinary fields and experience and intertwined these different strengths to achieve a better product for our students. We are confident that, with this cross-disciplinary collaboration, we have produced materials of real value to our students.

Challenges of implementing writing tuition across a program

There were several challenges to embedding writing tuition in established, core chemical engineering courses. These included:

- The established engineering curriculum is full. Finding a place to add in additional lectures and assessable writing workshops is difficult. We found that the buy-in from academic staff was most successful when they understood the importance of effective writing in industry and were able to make room in their established curriculum for explicit instruction. In the future, we face the challenge of gaining the acceptance and cooperation of staff who do not share this same appreciation of embedded writing instruction.
- Undergraduate students were less inclined to engage in the writing tutorial activities where there were no marks assigned to the writing activities. While most course coordinators were comfortable in assigning presentation marks for reports, some

were unwilling to change the well-established assessment schedules to support additional writing activities. Once again, buy-in from academic staff was strongest from those who appreciated the value of effective writing in industry.

- Delivering timely, relevant feedback on technical writing is challenging and time-consuming. Engineering academics may not have the necessary skills to give effective writing feedback and some are reluctant to increase their marking times to give this specialist writing feedback. We aim to mitigate this problem by developing and using clear and consistent marking rubrics that reward effective writing.

Conclusions and future research

We feel that, in spite of the challenges of embedding technical writing tuition in core chemical engineering courses, there is value in persisting with this pilot program. Engineering firms highly value strong writing skills in engineering graduates. The students' need for writing support is great and most students can see the value of participating in specialist writing workshops.

To date, the pilot project has produced:

- a permanent and sustainable change to the second-year core chemical engineering curriculum to include a technical writing lecture and workshop
- a small but growing set of technical writing resources that are being shared with other academics in the School of Chemical Engineering and across the wider EAIT Faculty.

There has been encouraging interest in the pilot project from engineering academics in the School of Chemical Engineering and from other UQ engineering Schools. Our plans for maintaining the program also include implementing a student-led peer-writing support program to encourage the practice of effective technical writing skills.

We expect that the future work will continue to embed technical writing components across the School of Chemical Engineering and across the Engineering faculty more broadly, including structuring out-of-classroom materials and resources for students to access and thereby enhance classroom-based learnings.

References

American Society of Mechanical Engineers (2011). *The state of mechanical engineering: today and beyond*.

Ardington, A. (2011). Writing: An Essential and Powerful Communication Tool for Today's 'Three Dimensional' Engineering Graduate. *Journal of Academic Writing*, vol. 1, no. 1, 61-70.

Beer, D.F. and McMurrey, D.A. (2014). *A guide to writing like an engineer*. 4th edition, Wiley;

Bruner, J. (1960). The process of education. Cambridge, MA: University of Harvard Press.

Boyd, G. & Hassett, M.F. (2000). Developing critical writing skills in engineering and technology students. *Journal of Engineering Education,* vol. 89, no. 4, 409-413.

Damron, R., & High, K. (2008). Innovation in linking and thinking: Critical thinking and writing skills of first-year engineering students in a learning community. *Frontiers in Education 2008,* 16-21.

Engineers Australia (2013). *Engineers Australia National Generic Stage 1 Competency Standards — 2011 (updated February 2013)*, viewed 21 August 2016, engineersaustralia.org.au/sites/default/files/shado/Education/Program%20Accreditation/140203_foreword_to_stage_1_standards.pdf.

Felder, M. & Brent, R. (2003). Designing and Teaching Courses to Satisfy the ABET Engineering Criteria. *Journal of Engineering Education*, vol. 92, no. 1, 7-25.

Fernandes, A.S.C. (2012). Writing to learn writing skills — a case study. *European Journal of Engineering Education,* vol. 37, no. 2, 179-192.

Graduate Careers Australia (2014). *2013 Graduate Outlook Survey: A Summary Report for Construction, Mining and Engineering Employers*, Graduate Careers Australia, Melbourne.

Horstmanshof, L., & Brownie, S. (2013). A Scaffolded Approach to Discussion Board Use for Formative Assessment of Academic Writing Skills. *Assessment & Evaluation in Higher Education,* vol. 38, no. 1, 61-73.

King, R. (2012). *Engineers for the future: addressing the supply and quality of Australian engineering graduates for the 21st century*, Australian Council of Engineering Deans.

Lang, J.D., Cruse, S., McVet, F.D., and McMasters, J. (1999). Industry expectations of new engineers: a survey to assist curriculum designers. *Journal of Engineering Education*, January, 43-51.

Lattuca, L., Terenzini, P., & Volkwein, J. (2006). *Panel Session — Engineering Change: Findings from a Study of the Impact of EC2000*. Paper presented at Frontiers in Education 2006.

Lee, T. (2003). *Identifying essential learning skills in students' engineering education*. Paper presented at the Learning for an unknown future, 26th HERDSA annual conference, Christchurch, NZ.

Lord, M. (2013). Delivering Diversity. *ASEE Prism,* vol. *23, no.* 1, 26-31.

Lowden, K., Hall, S., Ekkiot, D and Lewin, J. (2001). *Employers' perceptions of the employability skills of new graduates*. Commissioned by the Edge Foundation, The SCRE Centre for Research in Education, University of Glasgow.

Manion, P. & Adams, D. (2005). *When less is more: integrating technical writing instruction in a large, first-year engineering course*. Paper presented at the 2005 American Society for Engineering Education Annual Conference & Exposition.

Macdonald, C. (2016). *Teaching writing skills to engineering students: experiences and findings from the literature*. Unpublished paper. The University of Queensland, Brisbane.

Missingham, D. & Matthews, R. (2014). A democratic and student-centred approach to facilitating teamwork learning among first-year engineering students: a learning and teaching case study. *European Journal of Engineering Education,* vol. 39, no. 4, 412-423.

National Academy of Engineering (2004).*The engineer of 2020: Visions of engineering in the new century*.

Petelin, R. (2012). *Teaching writing*. Unpublished paper. The University of Queensland, Brisbane.

Petelin, R. (2016). *How writing works: A field guide to effective writing*. Sydney: Allen & Unwin.

Rhoulac, T.D. and Crenshaw, P. (2006). *Preparing Civil Engineering students to met workplace writing expectations.* Paper presented at the 36th ASEE/IEE Frontiers in Education Conference, 28–31 October, San Diego, California.

Robinson, C.M. & Blair, G.M. (1995). Writing Skills Training for Engineering Students in Large Classes. *Higher Education,* vol. 30, no. 1, 99-114.

Skinner, I., & Mort, P. (2009). Embedding Academic Literacy Support Within the Electrical Engineering Curriculum: A Case Study. *IEEE Transactions on Education,* vol. *52, no.* 4, 547-554.

Trevelyan, J. & S. Tilli, (2008). *Longitudinal Study of Australian Engineering Graduates. Graduates: Perceptions of Working Time*. Paper presented at the ASEE Annual Conference, Pittsburgh edn, vol. 1.

Trevelyan, J. (2010). *Mind the Gaps: Engineering Education and Practice*. Paper presented at the 2010 AaeE Conference.

University of Adelaide (2009). *Designing the future.* Engineering industry forum 2009.

Walker, K. (1999). Using genre theory to teach students engineering lab report writing: a collaborative approach. *IEEE Transactions on Professional Communication,* vol. 42, no. 1, 12-19.

Wilkes, J., Godwin, J. & Gurney, L.J. (2015). Developing Information Literacy and Academic Writing Skills Through the Collaborative Design of an Assessment Task for First Year Engineering Students. *Australian Academic & Research Libraries,* vol. 46, no. 3, 164-175.

Yalvac, B., Smith, H.D., Troy, J.B. & Hirsch, P. (2007). Promoting Advanced Writing Skills in an Upper-Level Engineering Class. *Journal of Engineering Education,* vol. 96, no. 2, 117-128.