Using practice architectures to investigate the invisibility of writing practices in the engineering curriculum

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Abstract: Written communication is neither systematically developed nor practised in the engineering curriculum, despite expectations by universities and employers that engineering graduates will be proficient communicators, and despite interventions to develop students' writing. The gap in the development of students' written communication calls for an investigation into the continuing invisibility of writing practices in the engineering curriculum. The lens of practice architectures theory was used to explore how engineering academics view writing in their engineering subjects, and how they develop the writing practices of their students. Practice architectures theory sees practices as shaped by and shaping cultural-discursive, material-economic, and social-political arrangements. A qualitative study examined engineering academics' teaching practices and the extent to which writing is practised and developed within the subjects they teach. Results show the majority of engineering academics in this study view writing as separate from technical engineering knowledge. This impacts the prevailing teaching and assessment practices by not providing opportunities for writing to be practised and developed within the context of engineering education. Unless there is conscious inclusion of writing practices, prevailing teaching and assessment practices will continue to focus on the acquisition of propositional knowledge to the exclusion of the development of writing practices.

Writing practices; engineering writing; engineering curriculum; practice architectures theory

I. Introduction

A. Background

Despite evidence to the contrary, such as engineers who are highly proficient writers and the demand by employers for engineering graduates with highly developed written communication skills, the perception or belief that engineers do not or cannot write is widely held both within engineering and in the wider community [1-3]. This begs the question of what are the real and potential impacts of this belief. Further, what are the implications for the engineering curriculum, that the ability to communicate in writing - to evaluate, negotiate, critique, justify, challenge, persuade or advise - is not visible? It can mean that writing practices lack value for engineering students and engineering academics, and that the development of writing practices is not enacted, or is enacted in a piecemeal fashion throughout the engineering curriculum.

The lack of visibility of writing practices in the curriculum, with the associated disengagement of the development of writing in the discipline by faculty staff, is evident in engineering faculties throughout Australia and overseas, despite ongoing concerns about gaps in the development of engineering graduate capabilities of written (and spoken) communication, and of the quality of writing of engineers [4-10]. This is also despite the implementation of a wide range of studies, initiatives, strategies and programs to investigate and develop engineering students' writing abilities, dating from at least the 1980s [11-15].

Therefore it is important to explore why this is so: why does such an important aspect of being an engineer and of doing engineering continue to be invisible in the curriculum and in academic practice? The importance of written and spoken communication is clearly demonstrated by its inclusion in engineering faculty graduate attributes and in graduate outcomes by accrediting bodies such as Engineers Australia (EA), ABET (US) and the Engineering Council (UK). Yet the responsibility for the development of this attribute, and the visibility of writing in the engineering curriculum are much less obvious.

One perspective is that the prevailing engineering science-based curriculum in Australia and in the US [16-18] militates against the development of professional attributes such as communication, management and social and environmental responsibility. The engineering science approach valorises convergent thinking [18] and 'emphasizes the scientific and mathematical foundations of engineering, as opposed to empirical design methods based on experience and practice' [19].The academics who teach engineering science subjects often regard themselves as the guardians of the standards of engineering, hence the importance of the 'weeding out' culture which features both in the US and in Australia [16, 20]. They must protect engineering standards by making sure that the assessment of their subjects is rigorous, such as examinations that test individual acquisition of knowledge through working out of equations, multiple choice answers, reproducing correct formulae, rather than group work where students can 'cheat', or written responses that ask for evaluations, judgments, or applying solutions outside of textbook problems. The focus is on technical knowledge, well-structured problems and assessment practices that measure correctness of an answer rather than the process taken to arrive at the right answer. Such an approach tends to result in atomized learning; the more successful students adopt a mode of acquiring knowledge that focuses on passing exams, but they may not see links between

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theory and practice, or the links between one subject and the next.

Another consequence of the engineering science approach to the curriculum is that writing practices tend to be excluded, for any or all of the following reasons. There is no 'room' for writing; there is limited opportunity for writing (with tests, quizzes and final exams), and writing is a different kind of knowledge. Many engineering educators regard writing as an activity which is practised by practitioners of other kinds of knowledge, such as those in the humanities and social sciences. According to this view, writing 'belongs' to the disciplines of humanities or social sciences, rather than to the technical disciplines of engineering, science and IT. As reported in a study by [16] on the cultural landscape of engineering education, while most engineering faculty members believed that students should learn '…professional development and communication skills' as part of their preparation to become professional engineers, this information was 'marginalized in Professional Development courses…These courses were referred to by both faculty and students, as "soft" compared to the more technical "hard" courses' [16 p.13].

II. Problem

As noted in the introduction to this paper, writing practices are not part of the dominant narrative of the prevailing engineering curriculum. The prevailing view of engineers (both inside and outside the profession) is of technical problem-solvers [21] rather than as those who pose, frame and challenge the nature and type of problems. This view is reinforced by research conducted by Pawley [22]. Pawley identifies three ways that engineering educators define engineering: engineering as applied science and mathematics; engineering as problem-solving; engineering as making things (22 p.312). It seems that none of these definitions include writing as a way of practising engineering or as a way of learning the practice of engineering; indeed the language of engineering is described as the language of maths (p.313). Engineers use the language of maths to communicate, but this will only allow them to communicate within their discipline, not to people in other disciplines or outside academia (the rest of society). Writing is seen as a different kind of knowledge; it is often ambiguous and interpretive; it means many different things; it is difficult to say when it is right or wrong.

The perspective that there are different kinds of knowledge and different ways of knowing has been explored by a number of researchers, including Bernstein [23]. Bernstein defines two principal educational knowledge codes: a collection code, where knowledge is hierarchical and builds on what has gone before, and an integrated code where knowledge is segmented and relies on the insight or 'gaze' of the knower [23]. Engineering is classified by several authors [24-27] as a knowledge code, with a hierarchical knowledge structure [25]. There is less literature that classifies writing or writing practices as a type of knowledge, but Macken-Horarik claims that secondary school English is predominantly a knower code [28]. Perhaps part of the resistance of engineering education to writing is to keep engineering 'pure' and 'hard', and avoiding association with something as 'soft' as writing practices – writing seen as a 'soft' skill and being seen to be part of a 'soft' (humanities) discipline.

Engineering defines itself as a field that produces useful objects and resists seeing textual mediation as part of what engineering is [18, 29]. This meshes with the belief that the engineering science paradigm represents what engineering is in practice [22, 30]. Along with the engineering science paradigm is the focus on engineers as solving technical problems by themselves, as reported by [10].These elements comprise what are known in practice architectures theory (outlined in the following section) as the cultural-discursive arrangements of the meta-practices of the engineering curriculum which constrain writing practices as being thought of as part of engineering studies, by enabling the belief that engineering **is** mathematics and has no need for textual realisation beyond the language of mathematics.

III. Methodology & Methods

Recent research into education has used practice theory perspectives, which regard practices rather than individuals as the primary unit of analysis [31]. Focusing on the practice allows researchers to consider the interactions of objects, organisations, people, processes, relationships, rules and specific situations when developing an understanding of dynamic practices. Having practice as the unit of analysis acknowledges the situatedness of practices – that they belong to a particular place and time, and unfold in ways that are shaped by specific conditions [32, p.33] or arrangements [33, p.19]. Practice architectures theory [34] has evolved from Schatzki's practice theory [33], where the focus is on the site of practice, how the practice is conducted, its temporal and physical location, and the arrangements that hold it in place. PAT can allow investigators to see not only what is happening in a practice, but how this has come to be and why certain practices become 'the way we do things around here'. In addition to providing a lens to analyse practices and what lies behind them, PAT also provides the language to discuss the complex interplay of forces that create conditions in which certain types of learning are constrained and other types of learning are enabled. It does this by identifying three different kinds of arrangements that exist simultaneously in a site of practice, and which hold those practices in place: cultural-discursive arrangements, material-economic arrangements and social-political arrangements.

Cultural-discursive arrangements are resources that prefigure what can be said and thought about a practice (the sayings); material-economic arrangements include aspects of the physical environment, financial resources, and divisions of labour that shape the doings of a practice; social-political arrangements incorporate organisational functions, rules and roles that shape the relationships (relatings) amongst participants and non-human objects in a practice [32]. It is important to note that the arrangements should not be considered or analysed separately; they interact with one another to prefigure (but not predetermine) the happenings of a site of practice.

For example, what is thought and said about writing in the engineering curriculum (cultural-discursive arrangements)

interacts with how writing is developed and assessed in engineering subjects (material-economic arrangements), and both of these practice architectures interact with how engineering academics relate to their students as expert practitioners of engineering writing (social-political arrangements). Working in concert, these arrangements thus both enable certain teaching and learning practices of writing in engineering, and constrain others.

In this paper we use examples from a study that is investigating the invisibility of writing practices in the engineering curriculum. The study explores what engineering academics say and do about writing practices in the engineering curriculum. We are looking at the sites of practice of each of the participants to identify the practice architectures that prefigure the teaching and learning practices, such as the wordings in subject outlines and assessment documents, assessment tasks and weightings, time allocated to writing practices in class, and the relative importance placed on developing writing practices by the subject coordinators in their engineering subjects. We also look at the practices that are enacted in the context of participants' engineering subjects. The practices are what the engineering academics say and do in their teaching; how they relate to their students; and what the students are required to do in these subjects. These practices include opportunities for students to practise or develop proficiency in different types of writing, and approaches to assessment of student writing. An examination of the arrangements – the practice architectures – that hold the invisibility of writing practices in the engineering curriculum in place can provide an understanding of how this situation has come about, and suggest ways of making sustainable change.

The study comprises analyses of the sites of practices of nine engineering academics from five different engineering faculties in Australian universities. Engineering academics who coordinate an engineering subject in undergraduate or postgraduate degree programs in Australian universities were invited to participate in the study; subject coordinators were selected as they have a certain amount of control over the teaching and assessment of their subject. The participants were asked to provide relevant documents such as subject outlines, support documents and samples of student assignments if available. Published writing by the participants, available in the public domain, was also collected. The documents were analysed to identify practices of teaching, learning and assessment, and the participants were then interviewed using semi-structured questions to investigate how they view their students' writing practices, their own writing practices as engineers, and the writing practices of the engineering curriculum. Some participants agreed to being observed while teaching; the first author attended their lectures or tutorials and took notes, which were later transcribed. The interviews have been transcribed and analysed to identify emergent themes using Concordance [35]. These themes were then re-analysed against the documents and classroom observations to identify practice architectures and elements of practices. As per ethical requirements, all participants have been de-identified and are referred to by pseudonyms; their institutions are referred to by letters.

IV. Results and Discussion

Results reveal that the majority of engineering academics in this study view writing as separate from technical engineering knowledge. Further, the prevailing teaching and assessment practices constrain the learning of writing practices by not providing opportunities for writing to be practised and developed within the context of engineering education. There are examples of practices that enable writing to be developed, but they are isolated and not supported throughout the engineering curriculum.

A. Prevailing Practice: writing practices as separate from engineering technical knowledge

Writing is a different type of knowledge from engineering science (and related types of knowledge in the STEM domain). The evidence for this claim can be found in: cultural-discursive arrangements and sayings that separate writing practices from other types of learning, or that do not refer to writing practices in descriptions of what engineers do; material-economic arrangements and doings that do not include assessment criteria for writing within written assessment tasks, or that outsource the development of writing practices to academic literacy specialists (often outside the engineering faculty), or that see writing as competing for scarce resources (teaching time in class; time needed to mark writing); social-political arrangements and relatings that regard the development of writing practices as someone else's responsibility.

B. Examples from case studies

Felicity's site of practice is a third year subject in the electrical engineering discipline in University C, with a cohort of approximately 110 students. In her interview, Felicity was enthusiastic both about the subjects that she taught and her teaching. She welcomed the opportunity to be interviewed about what went on in her site of practice, although it was difficult to get her to answer questions about writing practices because she would reply by explaining what the students needed to do to demonstrate their technical knowledge.

There are five learning outcomes in the subject outline: 'On completion of this unit [students] should be able to…calculate and analyse loadflow and faults… Calculate power flow… Identify fundamentals… Explain principles… Select a suitable dc and ac motor…' (Felicity subject outline 2014 pp.2-3). The emphasis is very much on the acquisition of propositional knowledge, but two learning outcomes are worded as though they would require more than notation:

3. Identify fundamentals of power system economics, generation costs, tariffs, market rules and performance

4. Explain principles of single and three phase transformers operation and performance (winding, testing, losses and efficiency) (Felicity subject outline 2014 pp.2-3).

Yet there is no mention in the subject outline, nor in the interview, nor in the assessment documents, of any opportunity to practise this kind of writing. The writing of numbers (equations, formulae and calculations) is present, but this is not seen as writing by the participant and may not be seen as writing by students. The assessment tasks are reports but the

emphasis is on accuracy of calculations and solutions, although Felicity comments that students need to evaluate which is the optimum design:

…see you need to consider this as some sort of product that you are going to develop; that you are going to manufacture. You want to sell it. How do you provide information to make others convinced to buy such a product? (Felicity interview)

There are no criteria that ask students to provide this information, or that assess the evaluations that the students make. The report is more like completing a template than writing a report from scratch: 'There is a booklet that - they need to fill that booklet, answer all those questions' (Felicity interview). The report format seems to be in a loose bundle of papers and there is no mention of report structure: 'There is some sort of booklet, but in terms of report they need to provide some sort of thing like that. Yeah, loose bundle again' (Felicity interview).

The practices of writing an explanation, justification or evaluation are absent; the 'reports' in this subject appear to be sets of calculations and completed tables of information (no exemplar student reports were provided). There are also (as in all sites of practices) oral explanations given to the students (sayings) that are not evidenced in the documentation: 'Also, we try to explain - prior to each session we try to explain what we are expecting from these questions. For instance do they need to answer - just give a brief answer' (Felicity, interview). So each semester the same explanations are given, or similar, or different, depending on who is doing the explaining, and who is hearing the explanations. These cultural-discursive and material-economic arrangements interact to suggest the ephemeral nature of writing practices in this site of practice, and also pose the question of why this information is not included in the subject outline. The absence of this information about the writing practices in Felicity's subject could indicate an absence of writing practices or an 'absence' in Felicity's perceptions about what students should be learning and doing in her site of practice. The same practice occurs in the sites of other participants: what they tell the students is not what is written in the assignment description (Adam, Eric, Garth, Ivan). This cultural-discursive arrangement, this explicit documentation, can be part of a site of practice (in four sites it is present) but is often missing. Yet the descriptions of propositional knowledge assignment outlines are noticeably present and consistent across sites of practices, and appear to include all the relevant information that students need to complete the assignments successfully.

These practices consolidate the cultural-discursive arrangements and social-political arrangements that can be detected in many engineering subjects where writing or communication skills are seen as separate from technical knowledge, and not the responsibility of the subject coordinator to develop. In Felicity's site of practice, she does not need to show the students how to write a report because that is covered by another subject that students do which prepares them for report writing, presumably of all kinds of reports. Felicity does not know the name of the subject that the students do, nor the content of the subject, nor whether it is just for electrical engineering students or for all engineering students, or for all students in the faculty, which includes science and IT students. It can be seen from Felicity's comment below that she does not see her role as developing students' writing practices for engineering practice unless and until the students are doing a capstone or thesis:

Interviewer: How do you - the writing practices in your subject prepare the students for the writing practices of engineering?

Felicity: For this unit [course] they do not need to write too much. So we don't deal with this case…

Interviewer: How do your students learn or acquire those engineering writing practices?

Felicity: I think there is a - for final year project they will learn how to do so. (Felicity interview).

A comment from another participant, Garth illustrates the emphasis he places on practicing propositional knowledge in tutorials in his site of practice (a technical subject in civil engineering):

Garth: So we have too many things that we want to teach and we only have 13 weeks. So we actually use tutorial times…to teach something, do a practice. So I thought that is the best way to utilize the time but by doing that there's no practice actually for a student to improve their writing skill (Garth University C, interview).

This comment highlights two elements of practice that occur within five of the sites of practice being analyzed: how the focus on propositional knowledge squeezes out the development of writing practices, and how writing practices are seen as competing for time with the teaching of propositional knowledge. Six participants make comments that indicate they see writing as either/or: either they spend time in class practicing technical problems related to the content of their subject, or they spend time in class practicing writing, presumably without any content. Three participants in this study saw that writing practices could be used to develop students' understanding of their technical knowledge by asking them to evaluate, explain, justify or recommend particular methods, theories, or solutions. Furthermore, what is not said is also part of the cultural-discursive arrangements: if writing/communication is not listed as a subject or task learning outcome, it has no presence for the students. When this effect is multiplied over the majority of engineering subjects, the impact is strong and clear: engineering is about technical knowledge, and has little to do with communication.

C. Prevailing Practice: writing practices not practised or developed in the context of the engineering curriculum

The evidence for this claim is found in: cultural-discursive arrangements and sayings that see writing practices as not needing to be developed in the context of the subject being taught; material-economic arrangements and doings that assess writing (reports) without providing an exemplar or opportunities for formative feedback; social-political arrangements and relatings that relegate written communication to the lowest level of importance or that allocate insignificant assessment weightings to the quality of writing.

Table 1 summarizes the assessable writing tasks of all the participants, indicating the weighting of each task and whether students have opportunities to submit drafts and/or to receive formative feedback before being summatively assessed. As can be seen, six sites of practice provide no formal opportunities for submitting drafts or receiving feedback. The three participants who do provide opportunities for feedback have structured the writing tasks so that students are required to submit reports for peer review (Charlie) or for tutor feedback (Charlie, Damien, Harry). The range of weighted marks allocated to the writing tasks are shown, as well as the percentage of marks allocated for quality of writing in the assignments. Four sites of practice either do not include information about how or if writing quality is evaluated, or apparently allocate zero marks for it, while one site allocates 5% for correct spelling, grammar and neatness (Garth's site). All the sites of practice teach technical subjects with the exception of Charlie's site, which is a post-internship review subject.

D. Practices that enable the development of writing practices in the engineering curriculum

In contrast to Ivan's site of practice, the practice architectures of Damien's and Harry's sites of practice enable the development of writing practices by integrating propositional knowledge with writing practices through the emphasis (the social-political arrangements) on writing assignments and by providing formative assessment (the material-economic arrangements) on preliminary reports or drafts (see Table 1). The cultural-discursive arrangements and sayings of Damien's and Harry's sites of practice support the development of writing practices in the context of learning the propositional knowledge of the subject; the subject outlines and assessment task descriptions include specific explanations of approaches to the writing tasks and how to format the reports. Harry makes the point in the following comment that students start learning when they start doing, and that writing the lab reports encourages students to engage with the learning:

Harry: So we're asking them to look at what they've got, see how that relates to the theory and analyse things and tell us what they think about it in a fairly structured way. That's where they start actually learning the things. That's why we ask them to write reports, so they actually engage with it (Harry interview).

These practices demonstrate that the development of writing practices need not constrain the teaching of propositional knowledge, and that the development of one kind of knowledge can interact to enhance the understanding of other kinds of knowledge, as has also been shown in studies of student learning and writing in engineering courses [8, 11-14].

VI. CONCLUSION

Overall, the prevailing practices of the engineering curriculum tend to constrain the development of writing practices by positioning propositional knowledge as separate from the ability to write an evaluation or justification of this knowledge. The separation of these two types of knowledge also reveals the practice architectures of the engineering curriculum which interact to place propositional knowledge as of higher value than professional attributes, rather than enabling practices that integrate these attributes with the technical knowledge needed to become an engineer. The lens of practice architectures theory has provided a way of considering the engineering curriculum to see the interconnectedness of arrangements that keep certain practices in place, and which constrain the development of others. If writing practices are to be made more visible within the engineering curriculum, there will need to be shifts in how writing is thought of, spoken of, enacted and valued so that it is seen as integral rather than extraneous to engineering education and practice.

TABLE I. WRITTEN ASSESSMENT TASKS ALL PARTICIPANTS

participant	university	Written assessment tasks & weighting	% of marks assigned to writing quality	Practised or formatively assessed
Adam	A	3 reports worth 60% of total assessment	Not specified	No
Bernice	A	2 reports worth 40% of total assessment	25%	No
Charlie	A	1 reflective report worth 55% of total assessment	25%	Yes
Damien	B	Scaffolded writing tasks; 4 reports worth 70% of total assessment	25%	Yes
Eric	A	3 group projects worth 65% total mark: 1st project is basis of 2nd project which is basis of 3rd project	0%	No
Felicity	C	Problem solving task 40% (group + individual component)	0%	No
Garth	C	2* group projects worth 40% of total assessment	5%	No
Harry	D	3 lab reports: 2 formative, 1 summative 20%	25%	Yes
Ivan	E	1 computer report 9%, 1 lab report 10%	Not specified	No

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