Voice in first-year engineering design report writing: An academic literacies investigation

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ABSTRACT

CONTEXT

When students enter into engineering study, they are required to take on the ways of knowing and doing that characterise their chosen discipline. One of the primary means of doing so is through the writing they produce and, in engineering, one of the main genres of writing that students might produce is the design report. The design report, as a genre, is governed by certain conventions and requires unique ways of constructing an authoritative 'voice'. This is because it requires that students move from what is given (specifications and constraints), through what is already known (in the literature) in order to develop something 'new' (a proposed design).

PURPOSE OR GOAL

The aim of this research paper is to investigate how first-year mechanical engineering students demonstrate 'voice' in design reports submitted for assessment within an introduction to engineering design module. More specifically, attention is given to three areas in which 'voice' in an engineering design report is enacted: framing the design problem, synthesising the relevant literature, and demonstrating creativity during the concept generation and selection process.

METHODOLOGY

The design reports of first-year students who provided consent to participate in the present study were collected. Design reports were collected over a period of three years. In total, over 50 design reports were collected over this three-year period. These design reports were analysed using the technique of content analysis, which entails systematic analysis of the characteristics of a selection of texts. In this research, the characteristics of interest pertained to how students engaged with certain writing practices required within a design report such as, for example, describing the design concept selection process.

OUTCOMES

Analysis of the first-year design reports reveals the different ways in which first-year students demonstrate 'voice' (or not) through the various generic sections of an engineering design report. At the point of framing or understanding the design problem and context, a minority of students experienced challenges in this regard. However, students struggled to situate the literature in conversation with their particular design objectives and to engage in design as a creative process, rather than just a technical one.

CONCLUSIONS

The outcomes of this study may be used to inform ways to enhance engineering students' engagement with the techniques of design and design writing. Engineering students' literacy practices reflect their engagement with and understanding of engineering tasks and activities. While much attention is given to engineering as a structured and objective enterprise, limited attention is paid to engineering as a creative act in which the design engineer exercises substantial agency.

KEYWORDS

Engineering design; academic literacies; student writing; voice in academic writing

Introduction

When students enter into engineering study, they are required to take on the ways of knowing and doing that characterise their chosen discipline. One of the primary means of doing so is through the writing they produce and, in engineering, one of the main genres of writing that students might produce is the design report. The design report, as a genre, is governed by certain conventions and requires unique ways of constructing an authoritative 'voice'. This is because it requires that students move from what is given (specifications and constraints), through what is already known (in the literature) in order to develop something 'new' (a proposed design).

However, to achieve mastery of this genre and construct an authoritative 'voice', engineering students must be able to navigate this shift (from given to new) in a non-linear and iterative manner. This is because the stages of engineering design do not progress in a linear fashion i.e. engineering design is iterative in nature. This means that the students must demonstrate that they are able not only to communicate the specifications and constraints as well as analyse the literature, but also to use these to inform, justify and revise their decision-making in the process of developing something 'new'.

The aim of this research paper is to investigate how first-year mechanical engineering students demonstrate 'voice' in design reports submitted for assessment within an introduction to engineering design module. More specifically, attention is given to three aspects of 'voice' in an engineering design report: demonstrating understanding of the design problem and context, engaging with literature, and claiming agency in the design process (through concept generation and selection).

Literacy in engineering (design)

Barton and Hamilton (1998) argue that there are different literacies associated with different domains. This is because literacy practices are patterned by social institutions and power relations, with some literacies becoming more powerful than others (Barton and Hamilton, 1998). Individual's literacy practices are subject to change as new ones are acquired through informal and formal learning (Barton and Hamilton, 1998).

Barton and Hamilton (1998, p. 8) further define literacy events as "activities where literacy has a role" in that the idea of an event always presupposes a social context in which that event takes place, thus reinforcing the fact that literacy is situated. Texts are crucial to literacy events and the study of literacy is thus, in part, the study of texts and how they are produced and used (Barton and Hamilton, 1998). Thus, Barton and Hamilton (1998) define literacy as a set of social practices that are observable in events which are, in turn, mediated by written texts. However, design reports, unlike other literary genres, are often not easily accessible apart from internal reporting in industries. This creates a challenge for students to master those sets of social practices in the case of design literacy. As a consequence, students do not have a number of examples to study. Thus, students are reliant on two primary modes, namely guidelines for design report structure learnt through instruction in design courses and as presented in textbooks on engineering design.

Very few first-year students can be said to have mastered academic discourses. Instead, Paxton (2007) argues that they are in a process of acquiring those discourses and their current stage in that process is one of 'interim literacy'. Interim literacies refer to the transition from the literacy practices of the school and home to those of the university (Paxton, 2007). The authors observed in a previous study (Simpson and Bhamjee, 2017) that first-year engineering design students were in a state of interim literacy. These interim literacies represent an interim stage in the students' lives as their identities begin to shift as they become more closely apprenticed into academic discourse. The notion of interim literacies suggests that the acquisition of academic discourse does not occur in a simple, straight-forward manner (Paxton, 2007). In another study, the authors (Simpson and

Bhamjee, 2019) found that fourth-year students had overcome many challenges that first-years faced. However, the fourth-years still demonstrated a number of other challenges in terms of developing mastery of design literacy.

Interim literacies can inform teaching in that they tell us who our students are and where they come from, discursively speaking (Paxton, 2007). They inform transformation, because they force us to acknowledge that certain identities are privileged over others within institutions of higher education (Paxton, 2007). Because of this, certain students remain in an interim stage of academic literacy acquisition, which explains why so few 'working-class students' are successful at university and even fewer progress to postgraduate study. Interim literacies go some way towards explaining how education can serve to perpetuate social inequality (Paxton, 2007). Furthermore, an understanding of interim literacies forces university staff to acknowledge that academic literacies need to be mediated (Paxton, 2007).

This is particularly important in engineering design, where literacy is multimodal in that engineers utilize graphics and mathematics in conjunction with written text to construct meaning (Johri et al., 2013). Navigating the interplay between these modes is critical and core to meaning-making in design literacy. This is evident in the increased incorporation of computer-aided drawing (CAD) and computer-aided modelling (CAM), tools that first-years are not exposed to yet, in design reports in place of hand-drawings and 'hand' calculations.

Voice in academic writing

Our interest in voice in engineering design report writing stems from a seminal argument (amongst literacy scholars) made by David Bartholomae in 1985, that of 'inventing the university'. Bartholomae (1985) argues that when students write, they are required to take on the particular ways of knowing, selecting, evaluating, reporting, concluding and arguing that characterise each discipline within the university. That is, they have to (re)invent, through their writing practices, their chosen discipline.

This is tied to the notion of voice, because students are required to 'speak' as if they are design engineers (for example), even before this is true. This means, as Bartholomae (1985) points out, that students must, at least initially, bluff their way through (what Gee, 1996, later called 'mushfaking'), which causes problems, particularly in the ways students write. These problems stem from the fact that student-writers must assume the right to speak with authority, even before they truly possess such authority (Bartholomae, 1985). This remains true throughout their studies, and perhaps into the first few years of their career. Indeed, the focus of this research paper is on the sense of authority with which students write in their design reports.

This is in line with Paxton's (2007) notion of interim literacy. As Paxton (2007) argues, interim literacy can manifest in several ways: students may overuse 'informal' or colloquial language, they may try to borrow or mimic disciplinary discourse in ways that seem clumsy to experts, or they may simply avoid using specific terminology because of a lack of familiarity or comfort with it. Importantly, when students engage in 'fact-telling', this is another characteristic of interim literacy as such students are drawing on the writing practices that allowed them to succeed in school (Paxton, 2007).

In the literature on voice in academic writing, the concept of voice is often conceptualised in either of two ways: as individual expression and/or as participation (Lensmire, 2000; Kamler, 2001). Our concern is with the second aspect, voice as participation in the design practices associated with engineering, rather than with voice as a vehicle for individual expression. Voice as participation allows for recognition of the fact that there is no single, unitary voice that one 'possesses'; instead, students' writing voices are situated and multiple and may vary across contexts and texts (Lensmire, 2000; Kamler, 2001).

However, Lensmire (2000) offers a more nuanced understanding of voice that considers students' interim literacies. He argues that voice is about 'becoming'. In this view, voice is a

project: crafted over time and undertaken agentively by students. Engineering students are thus expected to appropriate the resources of engineering design report writing and assimilate these in order to develop their 'engineering design voice'. However, very few students will do this without some formal induction into the particular resources of engineering design report writing, and student agency is often stifled within engineering pedagogy rather than consciously developed, because of a focus on formal content and procedure.

Finally, the literature on academic writing highlights a number of formal, linguistic avenues for the study of voice in writing. In particular, Ken Hyland (1998, 2000, 2012) has examined how voice and stance in academic writing are constructed through linguistic strategies such as hedging, boosting, attitude markers, and relational markers amongst others. Lillis (2001) also refers to the notion of 'addressivity' which refers to how a student's text demonstrates their sense of their addressee. In this particular research paper, our concern is not with these specific linguistic aspects. Rather, we are concerned with how students' engineering design reports demonstrate participation (or not) in engineering design practices as measured through the 'authority' with which they use an engineering design voice in their reports.

Research Design

The design reports of first-year students who provided consent to participate in the broader study of which this research paper is part were collected. Design reports were collected over a period of three years. In total, over 50 design reports were collected. The number of students in the module varied between 92 and 115 over this three-year period. Each student over the three-year period was provided with an informed consent form and informed that their participation was voluntary and anonymous. The informed consent was based on the ethics approval that was sought and granted by the university.

These design reports were analysed using the technique of content analysis, which entails systematic analysis of the characteristics of a selection of texts (Neuendorf, 2002). In this research, the characteristics of interest pertained to how students participated in, or engaged with, certain writing practices required within a design report such as, for example, describing the design concept selection process.

The design reports were submitted for the individual design project in a first-year introduction to engineering design module. The brief for the project each year was to design a clutch system (including coupled shafts) for a passenger car, bus, and one tonne truck, respectively. Whilst the vehicle type varied over the three-year period, all other aspects of the project were identical. The students were required to submit a design report that documented the entire design process. The brief required that the report not exceed fifteen pages excluding front matter and appendices (such as manufacturing drawings). At the point where this assignment was introduced, the students had undergone a semester course introducing engineering design and an engineering drawing module and as such, were familiar with the engineering design process and development of engineering drawings. The theory related to design of friction clutches and shafts was introduced in the module.

Framing the problem

The first discursive move required in the engineering design report activity was for students to demonstrate their understanding of the problem by accurately framing it within the context for and objectives of the design. A majority of students, across all three cohorts, were able to do this in a manner that displayed strong design voice, or agency.

For example, Figures 1 and 2 are extracted from two student-participants' design reports. As can be seen in these examples, the students clearly and succinctly report on the objective of the design report ("This report presents…"; "The aim of this report is to…"). In addition, they locate this objective in a real-world problem and do so from an assumed position of authority

("Even the highest quality and most durable clutch is subject to operational wear and tear…"; "There is a need for a mechanical device…"). These students' use of simple, declarative sentences, and their confident assertions - that *all* clutches are subject to wear and tear (Figure 1) and that 'machines' (or mechanical devices) such as clutches exist to simplify everyday activities - demonstrate their confidence in their understanding of the design problem, rationale and objective, as well as the real-world implications hereof, albeit that, particularly in the case of Figure 2, these attempts at locating the real-world significance of the design problem are somewhat clumsy. In both cases, there are some grammatical issues and, in Figure 1, the introduction is rather short and does not fulfil all the generic conventions associated with an introductory section. However, these are structural and surface-related features that, while important, are of less concern in this research paper than the assured position from which these students write.

INTRODUCTION
This report presents the design of a friction clutch system of a manually operated passenger car. Even the highest quality and most durable clutch is subject to operational wear and tear therefore this design entails to reduce the amount of wear on a daily used clutch system of a passenger car.

Figure 1: Extract from design report - student clearly frames the objective

INTRODUCTION

In our everyday lives we always try to simplify things and to reduce the amount of effort we put in to everything we do. If we are able to do this the life becomes easier. Machines exist to make it easier for people to do work, or to do the work required for people. A useful machine reduces the cost and does the work required faster.

For a car it is desirable to be able to change the speed without having to shut down the car's engine. For example, a car needs to temporarily stop at a red traffic light and resume motion when the light is green. There is a need for a mechanical device that can allow this type of motion to occur without having to shut down or damage the car's engine or any of the shafts. This report contains information and the design of such a mechanical device.

Problem statement
Cars are required to have the ability to change the speed at which they travel without having to shut down the engine. This gives rise to the need for a mechanical device that can allow smooth changes in the amount of power transferred without disrupting the engines motion.

Aim
The aim of this report is to design mechanical device that enables interruptible power transfer between the engine's crank shaft and the transmission shaft(**clutch**). This includes the analysis and design of the shafts associated with the clutch system.

Scope and limitations
This report will focus mainly on the design of a friction clutch system that is used in a passenger car. It will not cover the design and analysis of any other type clutch system. The design will focus mostly on the passenger car clutch design and will briefly cover the information, analysis and design of the coupled shafts that are used in the clutch system. The detailed design of the crank shaft, drive shaft, gearbox and linkage mechanisms associated with the clutch are beyond the scope of this report.

Figure 2: Extract from design report - student frames the objective and contextualises its real-world significance

Some student-participants, however, struggled, even at this initial hurdle, to articulate the given design problem with confidence and accuracy. Often, students would not include any background discussion pertaining to the design problem or objectives. For example, in Figure 3, an example is shown of a student-participants' report that begins with the fact that "There [are] 3 types of couplings". In this example, the student offers no context for this assertion, and no indication of the overall aims and objectives of their report. Instead, they move directly into 'fact-telling', suggesting a lack of voice, agency and participation in the design process, even from the very beginning. This, however, was not the norm, as most students were able to articulate a clear design goal and context.
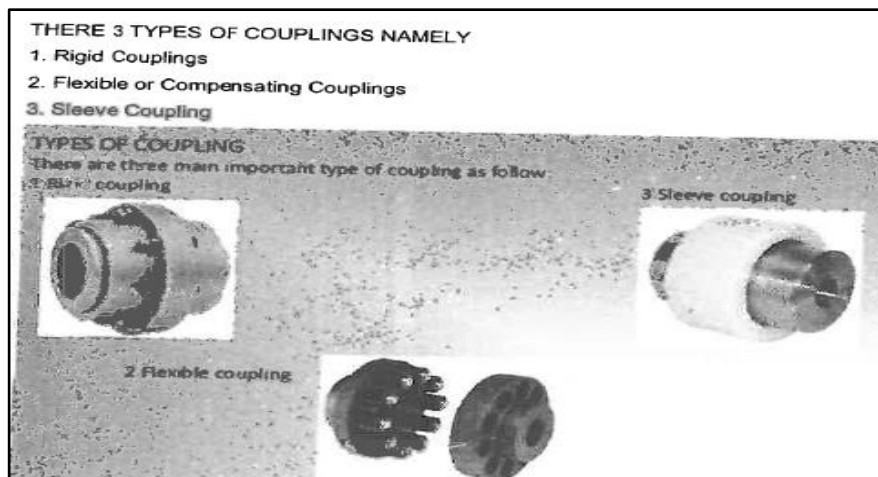

Figure 3: Extract from design report - student does not frame the problem and moves directly to 'fact-telling'

Synthesising the literature

While most student-participants across the three cohorts that were included in this study were able to locate their design report in a clear design goal and context, and many were able to formulate this design goal in relation to a real-world problem, a sizeable number of these student-participants struggled to maintain this design voice into discussion of the literature, or existing research related to clutch design. A complexity in the genre of the design report is that the literature review is not a critical analysis of the state-of-the-art in literature to highlight a 'research gap' as is the case in research report writing. Instead, in the design report, the literature review is a study of available solutions to the design problem and an analysis of the benefits and shortcomings of the available solutions. This must then be leveraged by the engineer in the design process when conceptualising potential solutions, selecting an appropriate solution and developing that concept into a working and effective solution to the design problem. Navigating this complexity is essential for students to construct an authoritative 'voice' in design report writing.

Figure 4 is an example of a student-participant that is able to relate the literature to their specific design problem and context. This can be seen in their relation of the idea of the centrifugal clutch to automobiles (the specific design context in that year) in the last four sentences of the paragraph. However, this is in sharp contrast to Figure 5, in which the writer resorts to list-making and summary and, in so doing, renders their agency, and their design voice, invisible. As Kamler and Thomson (2006) note, when the writer's voice becomes invisible, discussion of the literature becomes mere summary. In our study, we found that an extreme manifestation of this, but a common one, was an over-reliance on bullet-point listing of 'facts' about clutches.

Centrifugal clutches activate automatically when they reach high speeds that course a centrifugal force large enough that they reach the inner surface. These types of clutches are usually used to regulate the motion of motor pulleys, mainly because the activate at high speeds. This enable them to be able to keep rotational speeds above a specific minimum. This type of clutch could be used in an automobile, given that the springs have a low enough stiffness. However, some complicated linkage mechanisms and bearing would have to be used enable changeable power transmission. This type of clutch would be more difficult to make and would have to be custom made for all engines types with different output speeds and it would cost more to maintain. This type of clutch is not ideal for automobiles.

Figure 4: Extract from design report - student relates the literature to their specific design problem and context

Advantages of diaphragms.

   a. It's compact, less parts, less weight, less moment of inertia. Less maintance required and less assembly effort.

   b. Suitable for high engine speeds, as centrifugal force does not cause an imbalance as it does on coil springs.

   c. Low pedal force, less friction, better clamping force on friction facing does not decrease as it wears (it becomes more efficient).

There are currently three different types of pressure plates: The long style pressure plate, the Borg and Beck style pressure plate, but nearly all street-legal clutches use the diaphragm style.

   • Throw-out bearing - Provides a link between the rotating clutch assembly and the static clutch fork and transmission. It will also absorb the force to release the clutch and also reduce wear between rotating and non-rotating components.

   • Actuator lever - it absorbs the pressure from the clutch pipe and transmits it to the release lever.

Figure 5: Extract from design report - student relies on list-making and summaries

The literature review section, therefore, constitutes the first challenge faced by a majority of student-participants with respect to maintaining a 'designerly' voice in their reports. This is perhaps not surprising; as Kamler and Thomson (2006) further note, albeit with respect to postgraduate writing, the task of reviewing extant literature is to identify the ideas, principles and/or methods that are pertinent to the objective or goal and contribute to the motivation for the project. Kamler and Thomson (2006) locate the literature review section as a prime site for 'identity work', as writers need to locate themselves in relation to the literature. Depending on what literacy practices students bring with them, this process is easier for some students than it is for others.

Creativity and concept generation

Concept design is arguably the stage where agency and voice stand out the most in design literacy. In this phase, the student must leverage that which is given (problem, specifications and constraints) and that which is already known (from literature) to inform the conceptualisation and development of potential solutions to the problem. Furthermore, the student must use a combination of creativity and technical knowledge to develop unique and practical solutions to the given problem. Beyond that the student must be able to explain the operating philosophy and pros and cons of the concepts. Lastly, the student must provide an

objective opinion regarding which of the potential solutions is most viable to develop further as a final design.

A majority of students, across the three cohorts, struggled to meet the requirements to generate unique concepts, discuss their operating philosophy, merits and shortcomings as well as to provide an objective concept selection process. However, a sizeable number of students did demonstrate signs of agency and voice, and given intervention could demonstrate such clearly. That is not to say that none of the students clearly demonstrated agency and voice at this point, but that unlike in the earlier phases of the report, here it was more of an exception.

Concept generation and selection thus constituted the second point at which a majority of students' 'design voices' faltered. Moreover, there were particular patterns that a large number of student design reports followed in this section. In its most extreme form, this meant that students failed to generate any concepts, selecting one (or more) from the literature without consideration of the context or design problem. In such circumstances, students circumvented the need for creativity, and reduced the process to mere selection amongst alternatives provided by the literature. In this way, students avoided full participation in the design process.

In other instances, students did not engage in concept generation or selection, but did present a final detailed design. In these instances, creativity was backgrounded in favour of the more familiar practices associated with calculation, which was required as part of the detailed design. In these instances, students engaged in selective participation in the design process.

In those instances where students did develop discrete concepts, they often struggled to put forward an objective system through which to select a final concept for detailed design. In these instances, the students either applied unstated assumptions or personal preference, and the concept selection process remained hidden to the audience. There were very few instances, if any, where students revisited the design problem and literature to generate criteria and evaluate their solutions against those criteria. In some instances, students used scoring or ranking methods (often by way of a matrix), but there was seldom discussion of how the scoring was applied. These students show attempts at full participation in the design process, but greater development is still required in this regard.

Conclusion

In this research paper, we have identified three areas of an engineering design report in which first year students struggle to demonstrate voice or agency in their writing and, therefore, full participation in the engineering design process. The first of these is at the point of framing or understanding the design problem and context. However, only a minority of students experienced challenges in this regard. What we have shown is that the other two areas present as more significant points at which students' design voices falter. In the first instance, many of the student-participants whose design reports were analysed in this research struggled to situate the literature in conversation with the particular design objective. Furthermore, students' design voice and agency was even less present in the concept generation and selection process - where students struggled to engage in design as a creative process, rather than just as a technical one.

Of course, we do not expect first-year students to be expert designers. However, we do expect them to have gained some level of expertise by the time they graduate. And, we recognise that this expertise will not be developed without conscious mediation of the literacy practices through which engineering design is accomplished. Moreover, as Jacobs (2007) argues, the development of student academic literacies should not be confined to the first year only. Instead, attention needs to be given to what resources students bring with them into higher education - and to the fact that these resources may reflect high levels of social inequality prior to entry into higher education. Attention also needs to be given to how these

resources can be augmented throughout the curriculum in a way that fosters greater equality of participation. An engineering graduate that is clearly able to articulate a real-world design problem and draw on the literature and their own creativity to solve that problem should be the end-point of an engineering degree programme.

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