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New Literacies for Engineering Students: Critical Reflective-Writing Practice

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New Literacies for Engineering Students: Critical Reflective-Writing Practice

Abstract
Engineering education has long resulted in professional engineers with the required technical skills to meet the profession's needs. Yet in today's rapidly changing, globalised world, engineers will need more than technical competencies to meet the requirements of their professional work. Incorporating different literacies in engineering education might help with this shift. We introduce the idea of including critical reflective writing practice on the idea of being an engineer into engineering curricula. Our study explored how fourteen engineering graduate students were mentored on how to reflect critically on their professional identities through narrative writing. The students wrote the narratives while attending a pilot co-curricular Institute that focused on developing leadership, communication, and professional skill-building. We analysed the narrative writing produced by participants using the constant comparison method of analysis. Key findings show that (a) narrative methodologies are valuable for tapping into the reflective non-technical, process aspects of the profession; and (b) critical reflective writing practice was challenging for participants and required comprehensive scaffolding. If scaffolded and embedded in engineering curricula, critical reflective writing practice could contribute significantly to a 21st century engineering identity.

Depuis longtemps, l'enseignement du génie a permis de former des ingénieurs professionnels et des ingénieures professionnelles qui possédaient les compétences techniques requises pour répondre aux besoins de la profession. Pourtant, dans notre monde globalisé actuel qui change rapidement, les ingénieurs et les ingénieures vont avoir besoin d'autre chose que de compétences techniques afin de répondre aux exigences de leur travail professionnel. L'incorporation de diverses littératies dans l'enseignement du génie pourrait répondre à ce changement. Nous introduisons l'idée d'inclure dans le programme de cours en génie la rédaction réflective critique sur le fait d'être un ingénieur ou une ingénieure. Notre étude explore comment quatorze étudiants et étudiantes de cycle supérieur en génie ont été encadré(e)s sur la manière de réfléchir de façon critique aux identités de leur profession par le biais de la rédaction narrative. Les étudiants et les étudiantes ont rédigé des récits alors qu'ils et elles participaient à un institut pilote parascolaire concentré sur le développement du leadership, de la communication et de l'acquisition de compétences professionnelles. Nous avons analysé les récits produits par les participants et les participantes en utilisant la méthode d'analyse de comparaison constante. Les principaux constats indiquent que (a) les méthodologies de rédaction sont utiles pour aller puiser dans les aspects réflectifs non techniques de la profession; et (b) la rédaction réflective critique a présenté un défi aux participants et aux participantes et a exigé des échafaudages détaillés. Si la rédaction réflective critique est échafaudée et incorporée au programme d'études en génie, elle pourrait contribuer de façon significative à l'identité des ingénieurs et des ingénieures du XXIe siècle.

Keywords
engineering education, social justice, critical reflection, narrative writing, empathetic engineer; formation des ingénieurs, justice sociale, réflection critique, rédaction de récits, ingénieur emphatique

Cover Page Footnote
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While engineering curricula are designed to produce high levels of technical competency among graduates, there is increasingly a call to incorporate a critical awareness of "working and living ethically in a global community" (Cumming-Potvin & Currie, 2013, p. 21). This involves the incorporation of different, perhaps new, literacies in engineering education including critical reflective writing practice. These are literacies beyond technical ones that have traction in other programs but may be newly-emerging in engineering. The purpose of this paper is to explore a set of literacies around critical reflective writing. The study focused on graduate engineering students who attended a five-day pilot Institute aimed at fostering critical reflection skills within engineering pedagogy and practice. The paper begins with an overview of the calls for a different kind of engineer in the future and the need for educational shifts to accompany these broader global transitions. The next section on academic literacies provides the theoretical framework for the study and situates critical reflective thinking as a literacy that can be introduced into engineering curricula to support these broader shifts and to help foster diversity and inclusion in engineering. Following this, the research context, methodology, data collection, and analysis strategies are presented. The findings from the data analysis come next, followed by the discussion and conclusions.

Shifts in Engineering

The technical focus of engineering education has long resulted in professional engineers with the required and necessary skills to provide technical solutions to meet society's needs, yet these solutions may not necessarily be the most appropriate if the broader environmental and socio-economic impacts of engineering are not taken into account (Cumming-Potvin & Currie, 2013). In today's rapidly changing, globalised world, engineers need more than technical competencies to meet the requirements of their professional work. Indeed, engineering education is tasked with producing engineers with wide-ranging skills who can meet society's most critical needs. Meeting the "Grand Challenges" as identified by of the National Academy of Engineering (NAE, 2008) requires engineers who have multidisciplinary knowledge and who are aware of social issues. These challenges require engineers to embrace the idea of engineering being a "people-serving" profession who are motivated to be involved in communities and the environment but who are also able to critically reflect on their roles in complex issues and to work globally. Catalano (2006) also suggests that for engineers to respond to the "challenge of peace, of poverty and underdevelopment, and of environmental sustainability" (p. 11) will require asking different questions. Instead of "what is to be solved," questions will need to move to "for whom is it to be solved?" Other questions would include: "What are societal implications? The global consequences? The effects on the natural environment?" (Catalano, 2006, p. 47).

Given the calls for engineering to shift its perspective from a dominant focus on technique and technology to include more considerations of social and ethical implications, we see also the need to consider how engineering identity shifts in the process. Dias (2013) raises three current tensions in the "Who am I?" question in engineering. The first is the tension in the engineer's sphere of influence and the balance between efficiency and harm. Are engineers doing more harm than good? Are techniques, logic, and efficiency more important than understanding the situated phenomena or the relationships involved? The second tension is the engineer's role as scientist or manager. Does engineering identity centre around producing something or making something happen? Or are engineers "holistic" managers who have to cope with diversity, cultural complexity and social relationships? The final tension is centred around engineering knowledge and the

conflict between practical knowledge on the job and theory learned at university. Of course, all these tensions materialise in different ways in different contexts with each individual engineer. What Dias (2013) suggests, however, is that to navigate these tensions, engineers will need other skills and knowledge in addition to technical expertise. One of these new skills is critical reflective practice: "reflection on one's professional practice generates practice based knowledge that is invaluable and very different from the theoretical knowledge that is embedded in 'technical rationality"' (Dias, 2013, p. 147).

Current engineering curricula generally emphasize mathematical and scientific reasoning with the focus on productivity, efficienty, safety, and cost-effectiveness (Cumming-Potvin & Currie, 2013). Recent accreditation requirements in Canada and the US require engineering schools to demonstrate that their graduates meet outcomes-based standards on attributes including ethics and equity, the impact of engineering on society and the environment, etc. (Engineers Canada, 2014, 2016). Yet, many engineers do not receive an education that cultivates an orientation towards critical thinking and reflective decision-making that would foster a deep understanding of such "non-technical" but vital aspects of engineering work (Riley, 2008). Riley (2008) argues that to effect change from within the profession in the direction of more socially-engaged or socially-responsible engineering, engineers need to cultivate critically reflective skills that will help them more seriously question the role of engineering and the engineer in society. Allowing space for critical reflection during one's professional development might also allow space for more diverse views to be included in the profession and in engineering education. Foor et al. (2007) illustrate the many underlying beliefs that continue to provide barriers to diversity in engineering. Similar to Foor et al. (2007), we make the argument that changes in curriculum and pedagogy are necessary "to accommodate different ways of knowing or learning" (p. 112).

Academic Literacies

Cumming-Potvin and Currie (2013) suggest critical reflective thinking as a new set of literacies that need to be included in engineering curricula. The focus on literacies instead of literacy, which traditionally refers to learning to read and write, is deliberate. The idea of literacies refers to a theoretical base, "academic literacies", a framework that informs this study. This is an established framework that relates pedagogy to disciplinary epistemologies. Academic literacies is an approach to learning in post-secondary contexts that emerged in the 1990s from the United Kingdom (Lea, 2004; Lea & Street 2006, 2014). This approach sought to understand the range of literacies required of students to succeed both at university and in professional contexts (see, for example, Lillis et al., 2015). Many literacies are not explicit; students often struggle to decode specific disciplinary academic language. Writing tends to be the focus of an academic literacies approach because assessment often takes place through writing, and writing is the conduit through which many other literacies (reading, critical thinking, etc.) are performed (Russell et al., 2009). Academic literacies is also an ideological approach in that literacies are not viewed as superficial communication skills that need to be acquired but rather are deeply held, sometimes conflicting epistemologies that exist in academic disciplines. When students participate in the literacies of their discipline, they begin to develop their identities in that discipline. These literacies, however, have to be explicitly taught in university contexts, including contestation over what these literacies are (Cumming-Potvin & Currie, 2013).

Critical Reflection

Reflective practice is not new in engineering education although it is by no means mainstream. Many have drawn on Schön's (1987) work on the "reflective practitioner" and how "reflection-in-action" and "reflection-on-action" can influence professional education (Adams et al., 2003; Hicks et al., 2014; Lindsley & Burrows, 2007; Nilsson, 2013; Ryan, 2011). In this conceptualisation, the reflective practitioner frames the problem, makes decisions about how to deal with the problem and acts to address the problem and then reflects on the outcome. Other researchers have emphasized the value of reflective thinking and underline the point that students often do not learn from experience automatically (Verdonschot, 2006). Instead, reflection as an intentional and dialectical way of thinking about an experience to inform future actions needs to be methodically encouraged in engineering education (Turns et al., 2014).

However, many note that reflective thinking and practice is not easy to implement in engineering classes because of the difficulty of overcoming entrenched engineering "mindsets" and resistance to reflective practices (Doel, 2009; Muller, 2015). Doel (2009) found that it took fourth-year engineering students in the study "a while to get used to" (p. 170) reflection activities as they found this kind of writing and processing very different from their usual assignments. In many professional practices, reflection can become routinized and uncritical (Galea, 2012). Uncritical reflection can, then, re-enforce bias, inequalities and discriminations rather than expose them. Schön's concepts have also been criticized for not moving beyond the immediate context and for potentially preserving hegemonic or normalising forms of practice without enacting change at a broader levels (Ryan, 2011). A way around this is to extend reflection to reflexivity which includes a critical component (Bolton, 2010). While reflection is examining what we think, reflexivity (critical reflection) is the ability to look back in on ourselves, to recognise our own influence, within a context, as an agent in the practice we are involved in (Thompson & Pascal, 2012). Sakellariou (2013) suggests that in engineering, reflexivity "relates to evaluating the meaning of engineering work in society" (p. 27) and as well as developing engineering identities inclusive of diversity. In this paper, we explore critical reflection as a set of academic literacies among a cohort of engineering graduate students.

Study Context

Our team has been active in research on academic literacies in engineering (see Badenhorst et al., 2014, 2015). In response to growing calls to include critical reflection and empathy in engineering education, we received funding to develop and initiate a a five-day pilot offering of a co-curricular course called the "*Lead by Design* Institute on Leadership, Diversity and Dialogue for Graduate Students in Engineering." We targeted graduate students since they are potential leaders in the profession. The Institute ran in the Spring inter-semester break; sessions were held daily 9am-3pm, with one evening session, and daily homework.

Institute Pedagogy

We built the pedagogy around critical reflection and the idea that students should become aware of their knowing (their own thinking) and be willing to engage in engineering virtues (being responsible for their thinking/actions), and that this would result in questioning themselves and the character of engineering. Ethics, empathy and changing engineering identity were themes that

infused the Institute and critical reflection through writing was the mechanism of engaging participants (Table 1, see Appendix A for a more detailed description of the pedagogy). The themes for each day were: "What is engineering?" (Day 1) "What attracts you to engineering?" (Day 2) "What is the empathic engineer?" (Day 3) "How can I re-engineer the foundations of my career?" (Day 4) "Now, what is engineering?" (Day 5). In addition, the curriculum was developed around three interwoven pedagogical threads: (a) dialogue and the social context of engineering; (b) self-awareness, self-leadership, and inclusion of the self in the technical aspects of engineering; and (c) critical reflective practice. We recognised the difficulty of developing this critical reflection as a set of literacies in the one week of the Institute, given the lack of a deep writing culture or of reflective practices in most engineering curricula. However, we wanted participants to move towards becoming critical thinkers who "need to think autonomously, examine a diversity of perspectives including macro level and non-Western perspectives, and apply questions that arise from morally deep or caring perspectives" (Riley, 2008, p. 112). We used narrative writing as the means to develop literacies such as critical reflection.

Table 1

Overview of Developing Critical Reflective Practice in the Institute

Daily theme	Overview of Content	Sample Activities	Development of Critical Reflective Practice
Day 1: What is engineering?	What is engineering? Grand challenges in engineering Writing narratives Critical reflection Leadership in engineering	Draw your ideal engineer Draw yourself as an engineer Free-write on these drawings Write: What is engineering not? What are the boundaries of engineering? How are these boundaries manifested?	Discussions on what critical reflection is? Reflective activities that involved writing/discussing Issues presented during the day

Day 2: What attracts you to engineering?	Diversity in engineering Gender in engineering Modes of thinking The citizen engineer	Students bring an object that represents their story as an engineer – telling my story	Reflect on object and identity, modes of thinking, citizen engineer and themselves. Re-write narrative, Narrative 2
Day 3: What is the empathetic engineer?	Values and motivations The empathetic engineer Ethical frameworks Embracing change	Written reflections: What does empathy, values and ethics have to do with engineering? What ethical frameworks do I need to be an empathetic engineer?	Discuss revised narratives. What has changed in your narrative?
Day 4: How can I re-engineer the foundations of my career?	Self-leadership Leadership Conflict management	Working on an engineering challenge in groups Working on individual narratives	How will I contribute to re-designing engineering?
Day 5: Now what is engineering?	Public policy, social justice and engineering What's missing in engineering education, specifically graduate education?	Written reflections on the group activity Reworking individual narratives	Present Narrative 3 to group

Research Project and Methodology

At the same time as developing and facilitating the Institute as a co-curricular course, we also conducted a study of the pedagogy of the Institute and have published results of the study (Moloney et al., 2015, 2016a, 2016b). For this paper we focus on a sub-question: Did participants became more critically reflective in writing practice over the duration of the Institute? To address the research question, a basic qualitative interpretive research design was selected as per Merriam (2009) because we wanted to access meaning, to understand processes, and to take the context into account (Leavy, 2017; Maxwell, 2013). In line with a qualitative study, we collected data in natural settings (the Institute) and from the participants as they engaged with the Institute's pedagogy. The extensive research data collected throughout the Institute included: (a) regular reflective free-

writing products by participants on several topics each day related to the daily theme; (b) a pre- and post-institute survey filled out by students at the beginning and end of the Institute, which indicated their familiarity with concepts introduced during the Institute and how they valued various aspects of the Institute; (c) detailed daily observations written by the researchers as participant-observers (per Merriam, 2009); and (d) a series of evolving narratives written by participants. While all the collected data inform this paper, it is the set of written narratives (d) that we focus on here because of the reflective nature of these written pieces. Students wrote one narrative and revised it twice, and these three narratives form the data for this analysis. The narratives illustrate the students' processes of learning how to reflect critically. We used narratives, an unfamiliar genre for the engineering students in the Institute, for several reasons. First, narratives are a cultural expression of a construction of reality. They are highly spontaneous while at the same time organized texts. When writing a narrative, the writer creates a world that is filled with meaning. Second, narratives encourage the author to focus on subjectivity, context and specific time-points (Connelly & Clandinin, 2006; Elliot, 2005). Since we wanted to counter the culture of disengagement, and nurture critical thinking, it was important that students locate themselves in time and place in their identity-stories. Third, in line with an academic literacies approach, although they may appear individual, narratives are always tied to larger collectives and we wanted students to be able to "see" how their narratives related to larger collective stories and then make conscious decisions about their identities as engineers.

We advertised the Institute (and research project) to engineering graduate students in our home university. Criteria for acceptance to the Institute included being a graduate student, being interested in diversity and leadership and being available to attend at least 80% of the Institute sessions. Fourteen graduate students from the Faculty of Engineering and Applied Science volunteered to attend the Institute and participate in the research project. Eight participants, self-identified, were female and six were male. One participant was from Canada while the rest were international students, originating from countries including Vietnam, China, Iran, Sri Lanka, Bangladesh, and Pakistan. The large number of international students possibly reflects the desire for these students to develop professional skills in research and leadership. Some students perceived their English writing skills to be a barrier but we did not experience an issue in communication. Four of the participants were PhD candidates and the other ten were Master's students. Their disciplines included Oil & Gas Engineering, Electrical Engineering, Mechanical, Civil, Ocean & Naval Architecture Engineering and Environmental System Engineering. Participants attended the daily sessions voluntarily despite busy schedules and large workloads.

The written narratives (1, 2, and 3) were analysed using the constant comparison method (Merriam, 2009; Savin-Baden & Major, 2013). This process involved the following steps: (1) Reading the narratives. The narratives were grouped according to Narratives 1, 2 and 3, and read/analysed iteratively until the data were saturated. (2) Coding and conducting a thematic analysis. In each reading of the narratives, keywords/codes were recorded. This involved noting events, relationships, actions, emotions, activities, interactions, consequences or patterns. To these we ascribed a descriptive label to convey the meaning of the code. For example, codes such as "factual accounts" came from reading entire narratives and noting similar patterns across the narratives. Codes such as "focus on math and science," "fixing things," "making things," and "creating change in the world" become categories such as "engineering as applied science and mathematics," "engineer as problem solver," "engineering as making things," and "engineering as making a difference," respectively. The outlier narratives could not be coded according to these categories, and we chose to discuss them separately. (3) Connecting strategies. Codes were

grouped into themes, and narratives were compared to each other and across the data set to establish the validity of themes.

Results

Participants were asked to write the first narrative (Narrative 1) in the pre-Institute survey on "Why I became an engineer." Students could potentially write between 200-1000 words in the last open-ended question of the survey. They then brought a copy of their Narrative 1 to Day 1 of the Institute. On the first day, we introduced the genre of narrative and explained the purpose of narrative writing and critical reflection (Clark & Rossiter, 2008). To bring in reflexivity, we explained that although stories and narratives are personal, they are also linked to broader cultural narratives. We live in what Sarbin (1993) calls "a story-shaped world" (p. 63), surrounded by narratives of all kinds that embody our cultural values (Clark & Rossiter, 2008). We draw on these broader cultural patterns or templates all the time although often these stories become taken-for-granted and are part of our less visible "common sense" knowledge (Abbott, 2008). We emphasized that narratives are important because, by nature, they are constructed to be heard and, as such, form a powerful means of human engagement both for identity-development and for connections with others.

The participants' first narratives were generally a paragraph long and averaged at 350 words with a range from 205 to 675 words. Participants were asked to revise their Narrative 1, in their own time, into Narrative 2 which they would submit on Day 3 to two facilitators who provided feedback. The average word count for Narrative 2 was 383 words with a range of 188 to 763 words. Some students wrote less than in their first narrative, choosing to cut while others added descriptive details and extended paragraphs but changed little else. We gave individual feedback to each student on Narrative 2. This feedback focused on drawing students' attention to their values, their identities as engineers, and showing them where they could be more specific. Once they received the feedback, they revised their writing into Narrative 3. Narrative 3 was, overall, substantially different from the previous two. The narratives had all doubled in size, and the average length was 665 words with a range of 377 to 1207 words. These word counts may not seem like much writing, but for these students who expressed that they found writing challenging—especially narrative writing—these tallys showed the effort, energy, and labour participants invested in the narratives. By Narrative 3, it was clear from the length and substance of the narratives that students had taken the time to work on their writing both in scheduled Institute time and in their free-time, despite the intense workload of the Institute and the evening functions. These narratives were more detailed, specific, and coherent when compared to the earlier narratives. Students incorporated our feedback and their understanding of daily discussions in the Institute around values, identity, and empathy into their narratives. Each participant read their narrative aloud to the group on the final day of the Institute.

As mentioned, for all the participants, Narrative 2 changed little from Narrative 1 beyond surface editing. We see this as evidence of the need for deliberate pedagogy on critical reflective practice and further emphasis that, as a literacy, this form of thinking and writing is unlikely to happen without intervention. Since Narrative 2 was so similar to Narrative 1, we only present analyses of Narratives 1 and 3 here (see Appendix B for an illustrative example of Narrative 1 and 3). We have removed identifying words or phrases and replaced these with elipses to ensure anonymity of participants.

Narrative 1

Below is an example of Narrative 1, written by Melisa[1]:

> I chose mathematics and physics as my major during high school. After getting my diploma I took the university entrance exam in 2007 in […]. Since my grade[s] [were] very good I got the chance to choose any field of engineering I liked. At that time my brother was [a] civil engineer and my sister was [an] electrical engineer. They explained a lot about their field of studies and how they can obtain their desired job in future and what type of career they are expecting. At […] University, where I accomplished my bachelor studies, there was a university open day, which gave me a very good chance to go and talk to many students in different fields and ask them about their courses, what they […] exactly study and what they are expecting to do in future. Finally, I got my decision and chose chemical engineering as my major. After finishing my bachelor[’s] I decided to find a job to be independent but unfortunately it didn’t become possible. As I mentioned […] my home country was […] and […] there was quite high demand for petroleum engineers and this encouraged me to pursue my studies in petroleum engineering. I decided to come to Canada because I knew that there are many people from different cultures and I liked to live abroad, so I applied to Memorial and fortunately got the admission of M.Eng. in […].

Three themes emerge from the analysis of all participants’ first narratives: (a) Factual accounts: the first narratives are written as factual accounts and centre around an emotionless, disengaged description of becoming an engineer that resembles a résumé; (b) Engineering identity narratives: many of the narratives drew on broader cultural templates of engineering identity; and (c) Outliers: some outlier narratives were markedly different from the others. Each of these themes will be discussed in turn.

1) Factual Accounts

Melisa’s Narrative 1 shows a factual account of how she became an engineer. She focuses on the technical aspects such as being good at science and math as well as career prospects. She mentions some role models (her brother and sister), indicating that there may have been some family pressure to pursue engineering but this is not discussed. She wanted to be “independent” but “unfortunately it didn’t become possible.” There is no mention of any angst around this outcome. Her move to Canada— “I decided to come to Canada” —also does not account for the trauma and loss of leaving her home country or fear or anticipation of arriving at the new country. Melisa’s Narrative 1 is illustrative of many of the first narratives from the participants. This factual recounting is not surprising since, as engineers, they would have been trained to focus on facts and the technical aspects of life. In research on narratives, identity, and engineering, Korte (2013) suggests that engineers tend to separate identities along a continuum: “At one end of the continuum is personal identity and the other is social identity” (p. 41). In Melisa’s narrative, her tone, choice

[1] All names are pseudonyms. Participants elected to choose their own pseudonyms, and we have respected their choice.

of description, and plot all focus on the social identity and on the public portrayal of an engineer. Of course, we recognise that identity is a process more than it is an entity and it is complex, dynamic, and often dependent on the context (Korte, 2013). We also recognise that constructing narratives is "an ongoing activity of making meaning or making sense out of chaos, and … for a level of coherence" (Korte, 2013, p. 44). People piece together a more or less orderly sequence from a chaotic mix of experiences for specific purposes. The narratives of the Institute were written within a university context, so it is appropriate that many read like a résumé. The stories they tell their friends of how they became an engineer might be very different. Yet, generally, 9 of the 14 participants described their narratives in these factual terms.

2) Engineering Identity Narratives

All the first narratives drew on broader narratives about engineering identities. Pawley (2009) identified three narratives common in engineering: engineering as applied science and mathematics, engineering as solving problems, and engineering as making things. Many participants began their narratives by describing how good they were at science and mathematics or how bad they were but overcame this problem during the course of their studies. The narrative of engineering as applied science and mathematics was the most common across the narratives. For example, "I had a special talent in Math since I was very young" (Jane); "I was very good at mathematics" (Colt); "All term exams, I got excellent marks for those and very low marks for other subjects" (Lily); and "I have always been interested in maths and physics even as a child. I remember that when I was just 4 or 5, before I even [went] to school, I would ask my parents to teach me how to play with numbers" (Sheri). Engineers as problem solvers was another common theme in the narratives and illustrate this broader narrative about engineering identity. For example, "you face different challenges, different problems in engineering…you need to use your brain to solve the issues rather than memorizing lots of stuff…Need to think about solutions and then solve it" (Colt); and "when I was working in industry, what I realized was that the most important thing is how we accept challenges and how long it takes for us to change and respond" (Lily). *Engineering as making things* was the third broader narrative that emerged from the data. For example, "when I was a little child, I had lots of Lego toys instead of [Barbie] dolls. I could play with them [the] whole day long and build…many constructions using the Lego bricks" (Tara) and Amy wrote about her father as her role model who would make and fix things around her community. Sometimes two of these broader narratives appeared in participants' narratives.

In addition to the three broader narratives identified by Pawley (2009), we coded another cultural narrative that emerged in a number of participant narratives: engineering as making a difference. For example, Tara's graduate research focused on pollution, and she wanted to "continue contributing myself to environment[al] protection and sustainable development"; and Kelly wrote "I am hoping that I can work on the development of technology that can help people […] conquer the challenge [of living in] harsh environment[s]." Since engineering as making a difference was an underlying theme in the Institute, we assume that the Institute attracted people who were already interested in issues of change and diversity.

3) Outlier Narratives

Four of the narratives were classified as outliers because they did not conform to broader narratives. Charlotte, for example, identified the root of her interest in engineering in science

fiction and creativity. Another student, Amy, began her narrative by writing: "If you had asked me when I was a kid what I wanted to be when I grew up, I probably would have answered with: artist or veterinarian…I liked to draw and I liked animals." Her father was an engineer, and he encouraged her to study engineering, but she only found "a niche" when prosthetic design caught her attention. Even then, she never felt like an engineer: "I did not fit into what I perceived as the traditional mold of an engineer." Stephen, whose whole narrative focuses outwards, stated that his reason for being an engineer is to make life better: "As [an] engineer …it really matters to me that I can do something which really improves our life." What makes Stephen's narrative an outlier is his vivid personal style of writing rather than the factual mode employed by other participants.

In Narrative 1, the social identity of engineer is most prominent. With the exception of the outliers, the focus of these narratives was on universalised narratives of engineers and the stories commonly heard about engineering. After conducting a written reflection on the process of writing the narratives, Kelly wrote: "The first time I [wrote] the narrative all I did was [count] the words." Melisa wrote: "At the beginning, it [the narrative] was very hard." Amy wrote: "Writing narratives was a challenge at first."

Narrative 3

The third narratives were much longer, detailed, descriptive, and substantially different from Narrative 1. Two significant changes occurred in the narratives: (a) narratives were more personal and less social; and (b) decision-making around becoming an engineer became more contextualised. Each of these themes will be discussed in turn.

1) More Personal, Less Social

These third narratives shift along Korte's (2013) continuum from social identity to personal identity. They focus less on the public portrayal of "engineers" and more on the author's personal story. There is increasing awareness of their own role in their social surroundings and of their own agency. Tara, for example, transformed her narrative from an accounting of her math and science grades to a story of how she loved the "claw crane" machine at her local arcade from a young age. The claw crane machine is filled with plush toys, and the player has to manipulate a joystick to win a prize. Her narrative is full of personal details about the experience of using the claw crane: "I moved the claw right up to the toy we wanted and pressed the button. The claw released slowly and trembling." The main theme was learning how to use the claw crane successfully. In her conclusion, Tara wrote: "When playing the claw crane, I used the ability of spatial thinking and the physical knowledge such as gravitational effects and falling angle…engineering happens everywhere." In this narrative, she shifts from being good at math and science, to a personal memory that strongly influenced her decision to become an engineer.

Amy titled her Narrative 3 as "From pencils to simulations: One engineer's story of survival." She begins: "I like pencils. Always have preferred them over pen or marker. Probably because a pencil allowed me to create but also easily fix my mistakes." Maxwell explains how he decided to become an engineer:

> As a student in high school I used to visit my father's oil refinery and take a tour with the Senior Engineer who would explain to me all the processes and mechanisms involved. I used to read articles and magazines while sitting in his

> office, on natural resources and its extraction and production, and it was then that I discovered offshore rigs and the life on those huge mega-structures.

These examples are representative of Narrative 3. The writing is image driven, more personal, and filled with people who matter to the writer. The personal and social identities begin to overlap in these narratives.

2) Decision-Making Becomes Contextualised

In the third narratives, participants began to link their decisions around becoming an engineer to specific events, instances, or people. This is significant because they begin to see agency in their choices. T. Smith tells this story: "My parent[s] had to go to work all day…I was alone at that time and small robots became my best friends…so, mechatronic engineering sounded good to me." Lilly describes how she found her first job. She went to a career fair at her university for final year engineering students. She decided to apply to a foreign company: "But they said 'Oh sorry, this might be a mistake; we have selected only male students for this job interview. This would be hard for a girl'…but I was not discouraged…I told them 'that's fine, just interview me. I am sure you will hire me.'" She got the "very tough hardcore engineering job." Kelly explains her decision-making:

> Since I was a kid, I was always fascinated by the huge tool box that belonged to my Dad... Dad was the problem solver in our house. Doesn't matter if lights went off or any appliances stopped working, … Dad would take his magic box and walk into the battle field like a hero and it never took him long to fix the problem. I gave all the credit to the tool box he had. ... I still remembered the first time I opened the box, a bunch of tools with all kinds of weird shapes [lay] in the box, some were really heavy, some were stiff and some looked scary. When I held them in my hands, I had no idea how they worked. Till that moment, I realized that the magic was not from tools, but from Dad himself. Starting from that time, I wanted to become a magician like Dad. Dad is a mechanical engineer and he has been working in the oilfield for almost 30 years.

The change in the narratives provides evidence that the students were beginning to reflect critically even if this process of literacy development had only just begun. The students themselves noted the significance when reflecting on writing the narratives. T. Smith wrote: "writing the narratives was a good way to redefine what I really think." Stephen wrote: "[writing the narratives] really helped dig out something [that was] important for me." Lilly wrote: "writing the narrative made it easier for me to open up." Kelly wrote: "[the narratives] reminded me why I am here, doing what I'm doing being who I am." These quotes indicate a nascent reflexivity. The personal is positioned, with agency, in the social. Students were beginning to understand their complex roles in relation to others. While this is certainly not an indication of students who are critically focused on social action, with continued reflection, we are confident that these students would further question their values, assumptions, and prejudices.

Discussion and Conclusion

Although difficult to write for students participating in the Institute, the narratives and critical reflection proved to be particularly powerful for them. In the anonymous evaluations of the Institute, one student commented: "It was not easy to look in the mirror and explore the deep thoughts in my mind." In the Post-Institute Survey, in reaction to: The narrative revision exercise helped me to understand my identity as an aspiring engineering professional, 7.1% of the 14 responses were neutral; but 42.9% agreed and 50% strongly agreed ($N = 14$).

There are two conclusions we would like to discuss. First, students overcame disengagement. We found that critical reflection narrative writing was valuable for tapping into the non-technical, ethical, reflective aspects of the field so important to diversity in engineering and to future engineering endeavors that acknowledge engagement with wider contexts. Through the narratives, we believe that participants were beginning to see broader cultural narratives in their personal narratives. While undoubtedly, this was still a new process for them, and they were new to this type of writing and reflection, we feel they began to question the narrative or identity that they automatically constructed in Narrative 1 and were able to rework the narrative into a more personal yet more contextually rich Narrative 3. As Pawley (2009) suggests:

> …naming the narratives also helps make them available for critical analysis. If we as engineering educators fail to name and unpack our own stories, we risk carrying on the way 'it's always been done,' maintaining the discipline upon its historical and arguably exclusive foundation. (p. 317)

Shifting towards critical reflection allowed students to bridge the more technical aspects of their work with a more socially aware professional identity as it expanded their notions of what it is to be an engineer. This emphasizes the importance of placing the self in the profession, and the self in decision-making around professional tasks if we want empathetic engineers (Cech, 2014).

Our second conclusion is that students developed new literacy skills. Critical reflective practice is not an automatic set of literacies. These literacies need to be explicitly, deliberately, and systematically developed over longer periods of time. Both reflection and narrative writing were new and difficult for participants. We provided comprehensive scaffolding by delivering content on critical reflection and narrative writing, by discussing the narratives continually through the Institute, and by requiring students to write multiple drafts with feedback. We feel we had only just started the process of developing these skills in the week we had available for the Institute, and a severe limitation of this research is the short time-span. Critical reflection is a complex intellectual and emotional process that takes time to develop. However, deep reflective skills can be taught with development and practice over time. Since critically reflective writing is not something that is highly fostered in engineering education (Goldsmith & Willey, 2016), a deliberate and overt pedagogy would be needed to encourage narrative and critical reflection literacies. Unless taught in an explicit systematic way, these skills would be difficult for students to develop on their own (Ryan, 2011). As Riley (2008) argues:

> Generally, engineering students learn to think analytically only in certain ways appropriate to technical analysis. For example, we learn to break problems down into small parts, solve the individual parts, and then work back up to a solution.

> We typically do not come away with the ability to think critically, to question what is given, or question the validity of our assumptions, because we are too busy learning the essentials of problem solving. For this reason, we often cannot see the larger context of the problem we are working. (p. 41)

Eriksson (2014) further supports this, arguing that it would be challenging for students to develop these skills on their own. Epistemic practices are difficult to recognize, explain, and align with practices, and learning how to reflect on these aspects requires a considered and explicit pedagogy. More effort needs be placed on reflective writing early in engineering programs, arguably from first year. Currently, reflection gets focused on design projects and team learning experiences, but not as much on their identities. While reflection is beginning to get more credit in undergraduate curricula, to take it to the next level would involve the reflexive aspect we have outlined in this paper. Professions such as nursing, social work, and medicine have perfected this more in their undergraduate curricula. Ideally there would be room for reflection in engineering even in the technical courses.

Questions of "Who am I?" play an important role in developing a professional identity. Undoubtedly, life stories unfold over time, and any of the students who participated in the Institute can and will re-write their narratives and change their identities. But what is significant about the research presented in this paper is that by the third narrative, participants were consciously thinking and reflecting on who they were, how they became that way, and who they wanted to be. We are aware that we only initiated the process. We also acknowledge that reflective writing is not easy to implement in engineering curricula, but we believe these new literacies can play an important role in developing a professional identity for 21st century engineers.

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Appendix A
Description of Reflective Thinking/Narrative Writing Pedagogy*

Day	Topic	Purpose/outcome	Content	Activities
Day one	Workshop on reflection. How to reflect? What does reflection mean? What does critical reflection mean?	To explain the value of reflective practice; to provide information on different ways of reflecting; and to suggest techniques that would make writing more personal and powerful.	Why reflection for professional development is important The issue of critical vs non-critical Suggestions for different methods of reflecting The implications of critical reflection Techniques – what personal writing looks like, detail in writing, free writing. Reading list.	Draw an ideal engineer. Draw yourself as an engineer. Free-write on the drawings and critically reflect. Free-write: What is engineering not? Are there boundaries to engineering? Reflect on your experience of drawing and free-writing.
Day two	Workshop on narrative writing. How can narrative writing help us?	To demonstrate for participants why narratives are a powerful tool for reflection and growth; and to reinforce techniques and tips for writing narratives first introduced in the reflective practice session.	What are narratives? Personal vs cultural narratives Why narratives are important? Tips and techniques Reading list.	Free-writing exercises on the theme of the day: What attracts you to engineering? etc
Day three	Workshop: “Telling my story.” Revising narratives, sharing & reflection	To reinforce the idea of narratives and critical reflection. Participants were asked to bring in an object that illustrated something about themselves and why they became an engineer.	Participants shared their objects and orally told their stories to the group. Discussions on narrative writing and critical reflection.	Using an object, tell the story of how you decided to become an engineer. Reflect on your Narratives 1 and 2. What would you add or change?

Day four	Reflections on learning from Day Three. Feedback and discussion on narratives.	To reinforce the idea of narratives and critical reflection. To provide an opportunity for participants to ask questions about their narratives, narrative writing and critical reflection and to dig deeper.	Participants wrote and shared their writing in class by reading it aloud. Discussions on narrative writing and critical reflection.	Free-writing exercises on the theme of the day: How can I re-engineer the foundations of my career.
Day five	Revising the narratives	To provide an opportunity for participants to share their narratives and demonstrate their critical thinking.	Participants shared their final narrative in class by reading it aloud to the group.	Sharing revised narratives

*This table reflects only one aspect of the Institute pedagogy – the focus on narratives and critical reflection

Appendix B
An Illustrative Example of Narrative 1 and 3

Note that the original language has been retained, only identifying markers have been removed for reasons of confidentiality and privacy:

Nilgiri – Narrative 1

The following story makes me interested to study engineering for the development of my country as well as the improvement of the world community. In …, after completion of [high school], most of the bright students have a dream to make himself/herself admitted in the … University of …, the leading engineering university of the country. The admission test is highly competitive. Every year, only … students throughout the country … get the opportunity to sit for the admission test, whereas only …students have been finally selected based on their merit score of the test. There are many causes which induce/motivate these good students studying engineering at …facing all those difficulties. First of all, more than 75% students completed their graduation from this university, are successful in their respective fields, not just in the nation but throughout the globe. Secondly, it is the only university which has been trusted by the people of …for any sort of engineering test, technical opinion & solution and the university is involved with any major development project of the country. Thirdly, it is the sole university in the country which is comfortably equipped with all the equipments required for operating engineering education in multiple fields/disciplines. Fourthly, this university also has a vast number of highly educated teachers/faculty people from multiple disciplines who completed their post graduate degrees (mainly PhD) from different renowned universities of the world…Besides the above mentioned story, all the surrounding establishments (e.g. Infrastructure, entertainment) and overall the basic needs of a human life are somehow connected to engineering & applied science, which greatly influenced me to choose engineering. In summary my opinion is that I choose engineering to become financially solvent, get social respect and also do something for the community. Finally, being a …engineer, I possess a dream to be a part of engineering community who can make a better world for our future generation.

Nilgiri – Narrative 3

The following story makes me interested to study engineering for the development of my country as well as the improvement of the world community. Being a citizen of a developing country, I grew up in an environment where hazards such as cyclones, river erosion, and floods were very common. Besides struggling with the natural calamities, financial solvency was an important factor for a typical middle class family that always played an important role to dream about future. In …, after completion of [High School], most of the bright students have a dream to make himself/ herself admitted in the … University of …, the leading engineering university of the country. The admission test is highly competitive. Every year, only … students throughout the country … get the opportunity to sit for the admission test, whereas only …students have been finally selected based on their merit score of the test. There are many causes which induce/ motivate these good students studying engineering at …facing all those difficulties. First of all, more that 75% students completed their graduation from this university, are successful in their respective fields, not just in the nation but throughout the globe. Secondly, it is the only university

which has been trusted by the people … for any sort of engineering test, technical opinion & solution and the university is involved with any major development project of the country. Thirdly, it is the sole university in the country which is comfortably equipped with all the equipment required for operating engineering education in multiple fields/ disciplines. Fourthly, this university also has a vast number of highly educated teachers/ faculty people from multiple disciplines who completed their post graduate degrees (mainly PhD) from different renowned universities of the world… The overall competitive approach and environment of the university helps me to develop my personal skills & problem solving capacity, confidence to handle any engineering challenge and to work hard even under pressure. Besides the above mentioned story, all the surrounding establishments (e.g. infrastructure, entertainment) and overall the basic needs of a human life are somehow connected to engineering & applied science, which greatly influenced me to choose engineering. Being a citizen of developing country, I was lucky enough to watch the construction activities (such as construction of highway, high speed rail track, bridges & culverts, high rise buildings, shopping malls, embankment) from my childhood which motivated me to choose … engineering as a profession. Education & food for all, trade, housing, transportation system, entertainment and above all national development strongly depends on the mentioned infrastructure construction and facilities. In summary my opinion is that I choose engineering to become financially solvent, get social respect and also do something for the community. Finally, being a … engineer, I possess a dream to be a part of engineering community who can make a better world for our future generation. I would like to make myself thirsty for knowledge & curious for new information throughout my life and prepare myself ready to face the engineering challenges as an engineer of 21st century. Moreover, I would like to share & utilize my knowledge for the development of my country as well as fight against the natural calamity & hazards. Above all I would like to see myself as an empathic, citizen and global engineer.