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How and when do Engineers in the mining industry in Australia learn about Safety Culture and start to associate it with their Engineering Identity?

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ABSTRACT

CONTEXT

After several high-profile accidents in the late 20th century, there was an increased effort to focus on safety within Engineering. This is now known as Safety Culture, and it has become a priority for many Australian mining companies. Most previous literature about safety culture is mainly focused on a company perspective instead of an individual one. Additionally, there is little research on an individual's development of safety culture. This study is building on the Engineering Research project "Investigating Safety Culture and Engineering Professional Identity in the Oil and Gas Industry" by Payne (2020) which started to investigate these issues.

PURPOSE OR GOAL

The study focuses on engineering within the Western Australian mining industry. The rate of deaths in the Western Australian mining industry has fallen since 2000, however, the incident rate has stayed consistent which highlights the need for continued focus on safety (Department of Mines Industry Regulation and Safety, 2020).

APPROACH

The qualitative research was conducted through semi-structured interviews of purposefully selected participants. The sample consisted of three main categories to create a matched sample, this was done to view a progression of understanding.

1. Current University students with no vacation experience.
2. Current University students with vacation experience in the mining industry.
3. Engineers working in the mining industry.

After transcribing, the data was inductively coded to identify recurring themes using the software Nvivo (Maguire & Delahunt, 2017). Thematic analysis followed the framework by Braun and Clarke (2006), which consists of data familiarisation, generating codes, searching for themes and review. An initial interview of the researcher was also conducted to acknowledge any biases that may be present before starting.

ACTUAL OR ANTICIPATED OUTCOMES

There were significant findings that were new, it was found that Engineers learn about safety culture through multiple avenues including University, Training courses, previous course-related part-time work or through the company culture. However, a transformative experience was required for a richer understanding of safety culture and for students to start to associate it with their engineering identity

CONCLUSIONS/RECOMMENDATIONS/SUMMARY

This study focuses on where students are learning about safety culture and associating it with their engineering identity. This research can be used to identify gaps in engineering education.

KEYWORDS

Safety, Engineering, Education.

Research Problem

"Safety Culture" is the result of high-profile accidents in the late 20th century, it is still a recent concept, which raises the question if it is being effectively taught in engineering education. To investigate this, a qualitative research approach was undertaken to determine when students, graduates and engineers learnt about safety culture and associate it with their professional engineering identity.

Literature

This study is building on the Engineering Research project "Investigating of Safety Culture and Engineering Professional Identity in the Oil and Gas Industry" by Payne (2020). It focused on defining safety culture, exploring how it is a part of engineering identity and how it is developed. Payne (2020) found that safety culture was a part of engineering identity in the oil and gas industry and was dependent on an individual's experience, with site experience and mentoring having an impact. Payne recommended research into how safety culture is developed and incorporated in engineering curricula, which this paper focuses on.

Safety Culture

Safety culture can be defined in layman terms as, "the way an organisation behaves with respect to safety when no one is watching" (McKinnon, 2013, p. 1). Reason (2000) argues that safety culture is becoming increasingly important in the workplace as we have reached a plateau of safety technology, as most incidents are now attributed to human error. However, safety culture is not a miracle, it is easy to have inflated expectations of what safety culture can achieve.

Safety Culture Development in a Company and Individuals

Hudson (2001) says that safety culture in companies correlates to increased trust, accountability, and communication.

Novak, Farr-Wharton, Brunetto, Shacklock, and Brown (2017) surveyed 284 Australian engineers and found that high employee individual commitment to safety was correlated to a high level of safety outcomes in a corporation. Stemn, Bofinger, Cliff, and Hassall (2019), found higher individual levels of personal elements such as care, respect, accountability, and coaching correlated with higher safety culture at a person's workplace. However, there are limited studies that focus entirely on an individual's perspective on safety culture.

Engineering Identity

Engineering identity "comprises the attributes, beliefs, and values one uses to define oneself in the profession of engineering" (Morelock, 2017, p. 1). Atman et al. (2010) noted most previous studies about engineering identity have been focused on evaluating engineering identity in an academic sense such as competence and technical skills. The studies do not cover professional soft skills such as a student's association with safety culture.

Safety Culture in the Western Australian Mining Industry.

In industries with risky conditions, such as mining, there is a focus on safety concerns (Bisbey et al., 2021). The safety behaviours survey from 2001, surveyed 14% of the WA mining industry employee found 44% of employees took shortcuts to meet production pressures (MOSHAB, 2002). This showed a culture that was in earlier stages of company safety culture development (Hudson, 2001). Figure 1 displays the count of mining fatalities in WA from 1980 to present, there has been a decrease since the early 2000s. This coincides with the first resources about safety culture on the WA Department of Mines website are from 2005 (Department of Mines, 2005). Thus, we can presume safety culture was starting to form in the WA mining industry in the early 2000s. The incident rate has stayed consistent at 2500 a year since 2010, demonstrating the need for continued focus on safety within the industry.

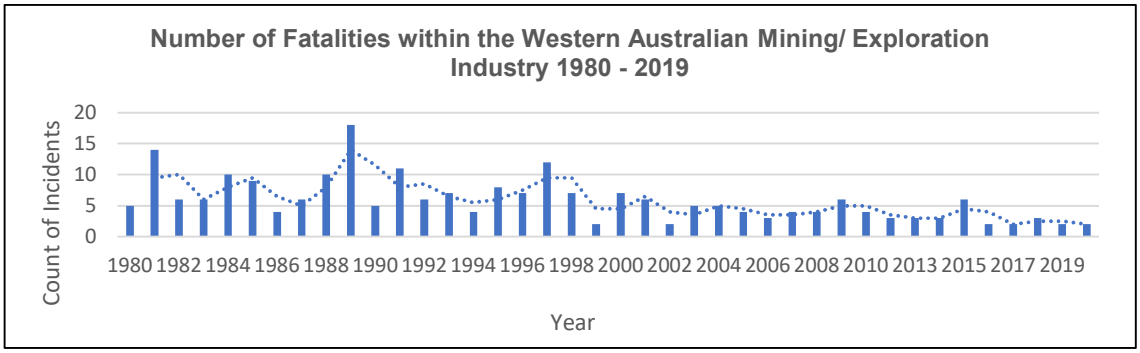

Figure 1. Number of Fatalities within the Western Australian Mining/ Exploration Industry 1980 – 2019 (Department of Mines Industry Regulation and Safety, 2020)

Safety culture in the Australian Engineering Curriculum and Teaching

Safety is covered in the Stage 1 competencies by Engineers Australia. As discussed by Male, Bush, and Chapman (2011), There is an increasing difference between what is taught at Australian Universities and what is required in the workplace.

Hamel (2018) says that safety is commonly taught using methods such as online quizzes and tests which are easy to mark and have paper documentation for legal requirements but do not effectively teach safety. Case studies if chosen and presented with intention can be powerful enough to impact one's own Engineering identity (Loui, 2005). Pitt (2012) found personal experience is essential when teaching safety, these can act as transformational experiences for students.

Research Question

There is a gap in the literature on individual association with safety culture and engineering identity. Mining is a high-risk industry, and many of the large mining companies in Australia list safety as a main priority. It is beneficial for mining companies to be hiring employees that already have a high safety commitment. One of the purposes of tertiary engineering education is to effectively prepare students for jobs in the industry, and thus safety and safety culture should be covered in the education of students. The study addresses the research question: "How and when do Engineers in the mining industry in Australia learn about Safety Culture and start to associate it with their Engineering Identity?

Theoretical Framework

Theoretical Frameworks have been used to guide the understanding and findings of this project. Social Identity Theory is a "person's knowledge that he or she belongs to a social category or group" (Hogg & Abrams, 1988). Loui (2005) studied found that students developed their engineering Identity by mirroring the engineers that they interacted with over their career. Constructivism is the idea that students gather ideas and then they construct the ideas in their own way (Zulkarnaen, 2019). Students build on their previous knowledge with new knowledge. As students have different vacation experiences this means they all have different "building blocks" of knowledge about safety culture.

Method

A qualitative research method has been chosen for this exploratory study as it suits topics that have minimal previous research (DiCicco-Bloom & Crabtree, 2006). Researcher bias was minimised through bracketing interviews where a preliminary interview of the researcher was conducted to acknowledge any assumptions, beliefs, biases, ideas, or perceptions that the researcher may have before starting the research process (Creswell & Miller, 2000).

The human research ethics approval was approved as an amendment for the "Virtual Work Integrated Learning Modules for Engineering". The interview questions were based upon the

questions by Payne (2020) and the framework by Kallio, Pietilä, Johnson, and Kangasniemi (2016) about developing semi-structured qualitative interviews. The interviews were semi-structured interviews conducted via Zoom or in-person for 0.5 to 1 hour. Participants were invited to complete a voluntary preliminary demographic survey before their interview. After the conclusion of the interviews, the recordings were transcribed, the data was then inductively coded to identify recurring themes using NVivo (Maguire & Delahunt, 2017). The thematic analysis followed the framework by Braun & Clarke (2006) which consists of data familiarisation, generating codes, searching for themes and review.

Data Collection

The participants were purposefully selected and invited to participate. For this project, a sample size of 6 interviews was conducted, as this captured recurring themes and "saturation" of opinions while also considering the limited timeframe to complete the project (Malterud, Siersma, & Guassora, 2016). The sample consisted of three main categories to create a matched sample and to view a progression of understanding.

1. Current University students with no vacation experience.
2. Current University students with vacation experience in the mining industry.
3. Engineers working in the mining industry.

Age, Demographic, Years of Experience, Industry

Participants were selected with purpose, to maximise the depth of data (DiCicco-Bloom & Crabtree, 2006). A mix of genders, ages, specialisations, and experiences was selected to capture multiple viewpoints. Mechanical and Electrical Engineering was chosen due to the prevalence of these disciplines in the mining industry. The concept of safety culture has only been very prevalent in the industry since the early 2000s. Engineers that finished their studies earlier than this would have learnt about safety culture while in the industry, thus were not selected. Safety culture is prevalent in other high-risk industries such as medicine, aviation or chemical processing, so participants with experience in these industries were not considered (Wiegmann, Zhang, von Thaden, Sharma, & Gibbons, 2004).

Before beginning the interview participants completed a demographics questionnaire and consent form. All participants studied or are currently studying at The University of Western Australia (UWA). The following abbreviations are used to discuss a participant's role and level of experience, for example, Participant A is a Graduate Mechanical Engineer (MG).

M – Mechanical Engineer
E – Electrical Engineer

G – Graduate/Working Engineer
V – Student with Vacation Experience
S – Student with no Vacation Experience

How and when do Engineers in the mining industry in Australia learn about Safety Culture

From my analysis, participants have learnt about safety Culture through the following methods.

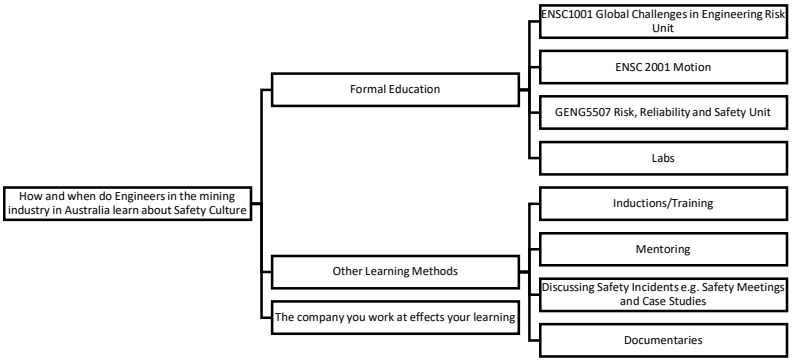

Figure 2 - How have participants learnt about safety culture?

Initial Understanding

First, participants were asked to define safety and safety culture to see if they understood the concepts before beginning the interview. There were various levels of understanding of safety, participants with work experience had a richer understanding of safety which was more in line with the formal definition. Participant A (MG) showed a deep understanding by defining safety in terms of emotional safety by mentioning mental health. Both students without any work experience, C (MS) and F (ES) believed safety was limited to the business and engineering work they performed and did not consider any human or people aspects of safety. Participant C (MS) did not mention keeping oneself safe or others safe and instead mentioned only keeping the business safe. Participant B (MV) & D (ES) both worked at Company A, a large mining company, and recited the company response of "going home at the end of the day in the same condition you went to work in.

Within the mechanical engineering matched sample there is evidence of growth for the definition of safety culture. Participant A (MG) had a comprehensive definition, Participant B (MV) was unsure of their answer, hesitating and saying "maybe" and Participant C (MS) was not able to put into words what they believed safety culture was. With more experience came a richer understanding of safety culture.

Formal Education

All participants besides Participant D (EG), who graduated in 2004, stated that they had learnt about the concept of Safety Culture while studying at university. The main areas that students learnt about safety culture at UWA were in the GENG5507 Risk, Reliability, ENSC1001 Global Challenges in Engineering and ENSC 2001 Motion. Participant E (EV) said that university was their "first exposure" to safety and that university "definitely like awoke me to the definition". Participant C (MS) said, "I think the foundations [of safety] was set at University."

However, learning about safety and safety culture at university seemed to only provide a surface level introduction to the concept. Participant C (MS) said learning about safety at university "was more of a formality" and that it felt "disconnected". They said, "If you're just outside of the realms, if you're wearing shorts and not long pants you can still get in". Participant B (MV) said they feel "protected" in the labs "not on the same scale, and the risks aren't as high as they are out on-site". While Participant F (ES) made the point that "a PowerPoint is different from an actual disaster".

Students are being introduced to the ideas of safety and safety culture while at university, however, they described this as feeling "disconnected", "formality", "wishy-washy", "not the same scale" & "fictionalised". This shows that although students learn about it at university, they do not associate it with their engineering identity at this time.

Inductions/ Training

Training by companies is a way to promote the safety culture they would like perpetuated within their company. Participant A (MG) mentioned that the induction and training modules that Company A provided had a positive impact on their safety culture. These introductions and training courses allow students to build on previous knowledge they learnt at university. Participant B (MV) said that on-the-job training such as "Take Fives" taught them about safety as "you really sit there, and you think about everything that could go wrong".

Mentoring

Dehing, Jochems, and Baartman (2013) mention that mentoring can develop professional identity, this is evident in the data. Participants D (EG), E (EV) and A (MG) all mentioned mentoring. Participant A (MG) said as a graduate "Your first learning experience will always be from your leader, if your leader focuses on safety more, the more you pick up from it".

Discussing Safety Incidents

Jamieson and Shaw (2019) discuss how safety moments can be used to effectively develop safety culture. A company can create a place where the values they would like are

emphasised. This can be done by structured and assessable parts of the job such as a Safety Meeting or Job Hazard Analysis. Participant A learnt about safety culture through daily safety meeting, these provided continuous learning and the ability to bounce off other people's experiences.

> *"An opportunity where you can identify risks on previous days and discuss that with your team and identify how we can mitigate them or make sure those risks are eliminated or making sure that they don't happen again."*

Participant B (MV) mentioned the importance of safety meetings for communication and gaining knowledge about safety and safety culture.

> *"Being involved in all the safety meetings ... You realise you don't have all the answers and you do need to rely on other people to manage the risks around you and to keep everyone safe."*

Participant C (MS) said that "Hearing about the bad stuff that happens in our case study. The big explosions and people dying sort of gives you that scare effect". Participant C (MS) believes that talking about safety was to scare you into doing the right thing, instead of for education and learning. They are not able to identify how to learn from safety incidents, Instead, they believe they are used to scare students from attempting similar things.

Participant E (EV) mentioned "listening from other people" as a large influence. The common theme from participants A (MG), B (MV) and E (EV) is that these experiences need to be non-judgemental and collaborative, they all benefited from the open discussion with other people about safety.

Documentaries

Participant F (ES) discussed how they found it easiest to learn about safety through documentaries on previous engineering safety incidents. These had a more profound effect on them than learning because they could "emotionally relate" and they found it hard to relate to PowerPoints or lectures at UWA.

Company Norms

Although a company cannot force their employees to associate their engineering identity with the company's safety culture, social identity theory suggests that over time employees will start to associate with the values of their work colleagues and those of the company (Loui, 2005). As discussed, the survey by Novak et al. (2017) found that a high level of safety outcomes in a corporation correlated to a high employee individual commitment. The findings provide evidence of this.

Participant E (EV) said, Company G, a Large Engineering and Design Consultancy presented them with one video about safety inductions while when they moved to Company A they undertook three days of safety inductions, they believed the extended safety induction changed their understanding of safety.

Participant B (MV) had work experience at two large mining companies, Company A and Company B. Company B had a reactive safety culture, which Company A had a preventative safety culture. When discussing the safety culture at Company B compared to Company A they said:

> *"It was different [At Company B] because the plant was so old that stuff just happened, so the way they managed the risk was a lot different." … "The safety culture [At Company B] wasn't preventing the incident; it was solving them after that happened."*

Participant A (MG) discussed Company A's focus on safety. It becomes clear that Company A had significant safety practices, however, Participant A (MG) was frustrated by the safety impacting their productivity and performance.

> *"it's all about safety. You can cut down on your productivity, but you cannot cut down on your safety process." … "We as a business may tend to sort of fall back on targets and might sort of create a lag in the workflow".*

Participant A (MG), B (MV) and (EV) had all worked at Company A and noted that this company had a stronger focus on safety than their other experiences. The company culture and norms at Company A impacted their understanding of safety. In the safety culture definitions, two of the four participants that worked at Company A easily recited Company A's definition of Safety Culture, showing that the definition was repeated enough that they picked it up. It is evident that Company A was in a later stage of safety culture development out of the different stages of safety culture, pathological, reactive, calculated, proactive, generative (Hudson, 2001).

Participant C (MS) worked at company D, an air-conditional installation company with a poor safety culture which impacted Participant C's individual safety culture. The following comment' show that Company D has a low level of safety culture development (Hudson, 2001). The participant made multiple comments that have been shown below for impact.

> *"What I've experienced when they know that there's a void in the documentation, they don't tell the people higher up because it results in more paperwork that they don't want to fill out."*
> *"You have to do something a little bit jank."*
> *"Getting the job done seems to take precedence over safety. ... They don't care, it costs money"*
> *"Theres like a pressure, to be like it's fine, sweep it under the rug, tick it off".*

According to Social Identity Theory, Company D is influencing the attitudes of Participant C (MS) (Loui, 2005). They do not appear to care about safety, shown by the nonchalant way they said "blah blah blah" while discussing risk.

> *"We're not sticking fingers into places that … Yeah, well, maybe I shouldn't say that sometimes we do. Everything is turned off, everything's isolated, blah blah blah. We know the risks".*

However, Participant C (MS) is aware that the companies' values do not align with their own believes and they want to change their values, this is discussed later.

> *"I want it to be sort of, my identity to be based upon those issues. Like I see the pain and the suffering that all these issues make, and I sort of want to not do that" … "So I want to be better than that".*

It becomes clear that where a person works impacts their understanding of safety. The company a university student does vacation work at during this formative time will impact their association with safety and safety culture.

When do Engineers in the mining industry start to associate it with their Engineering Identity?

Transformative Experiences

Students require a transformative experience to associate safety culture with their engineering identity, Tyng, Amin, Saad, and Malik (2017) found emotion has an impact on learning and creating memorable experiences. This experience will help them understand the importance of safety and safety culture. The three transformational experiences identified in the study are detailed in Figure 3.

Figure 3 - When do Engineers in the mining industry start to associate it with their Engineering Identity?

Site Experience

Visiting or working on a mine site was a transformative experience for participants A (MG), B (MV), D (EG) & E (EV). Participant A (MG) discussed their first project as a graduate engineer.

After investigating a incident on a ramp where the chocks were not properly in place they found that the ramp was also not rated for the weight. “There were more questions to be asked about how that can be improved and how that can be prevented.” Participant B (MV) identified learning about safety in university, but they only started to understand the implications of working in a safe environment when they saw it themselves, they stated that:

> *“When I started out [at company b] I was, you know, I was aware that I had to be safe, but walking around the site for the first time being like Oh my God, all this stuff could actually like really injure me. It is when you start thinking well. How can I protect myself? How can I protect those around me from being injured?”.*

Meeting Others

Participant D (EG) mentioned that meeting others who had safety incidents was pivotal in their safety culture learning.

> *“There’s lots of guys I worked with who were missing fingers because there are a lot of pinch points in a coal mine and just resting their hand or something, it gets squashed. So just stories like that, or there was an electrician who got severely burnt. Also meeting people like that, that was really, I think shaped how I think about it.”*

Safety Incidents

Another transformative experience was being involved with a safety incident. Although ideally these situations are avoided by companies, they still have a profound impact on those involved. Participant B (MV) explained how she was on site when a mayday call came through the radio about a casualty, she heard the whole interaction play out.

> *“That's very real and you're like oh my God, this is happening. We were just sitting in the car and you know, it's very almost confronting, like realizing you know, people do get hurt. It's one thing to read about it … but seeing an incident happen in front of you … you realize that you know this does happen, these are real concerns that need to be managed.”*

Do participants associate safety culture with their Engineering Identity?

Participants A (MG), B (MV), D (EG) & E (EV) all associated safety culture with their Engineering identity and identified transformative experiences that were pivotal points for them. Participant C (MS) had trouble defining safety culture and listing attributes that made a good engineer. Both C (MS) and F (ES) do not currently associate safety culture with their Engineering Identity. When asked if they associated safety with their engineering identity C (MS) stated:

> *“I want it to be sort of, my identity to be based upon those issues. Like I see the pain and the suffering that all these issues make, and I sort of want to not do that” … “So I want to be better than that”.*

Participant F (ES) said:

> *“it sounds like it's a lot of fluff, it's just like people talking and bullshit, so they can do the job and pretend to be doing something useful but, like they might be doing something useful, but they won't prevent a disaster”.*

No Vacation Experience

According to the constructivism theory of learning, students build on their past experiences (Zulkarnaen, 2019). Participant C (MS), a final year student did not have any course-related work experience when they studied the unit Risk and Reliability. They had no previous experiences to build on which led them to feel “disconnected” while studying the unit. When talking about a case study on Piper Alpha, an Oil Rig in the North Sea, the participant said

> *“I don't see me ever working on an offshore rig, like I don't see that. I mean I could I? But I don't see the lessons I meant to learn from it, that seems a bit too not relevant”.*

The student was not able to relate to the case study.

"Wow, a lot of people died. Not exactly sure how that Implicates me about how to do stuff better. I mean, I understand the processes and stuff that went wrong, but I've not done any work that like relates to it".

This lack of engineering vacation experience is hindering their formal learning of safety culture at university. Meanwhile, other students taking this unit may have been exposed to work like this in a vacation program which means they were able to relate to the content.

Participant F (ES) didn't consider personal wellbeing as being part of safety and believed that managing dehydration and heat stress was "pointless" it didn't "directly related to the job" and "I wouldn't care". They had a limited definition of safety and focused more on safety in terms of engineering design than human factor and behavioural factors and said "I would think safety is more to do with stuff". This shows the importance of having these transformative experiences early so that students learning is not impacted.

Significance of Findings

This study builds on the study by Payne (2020) and confirms their findings that Engineers do associate their professional identity with safety culture and experience and mentoring have an impact on a person's individual safety culture. The findings about how safety culture is taught are consistent with those in the literature such as safety moments by Jamieson and Shaw (2019) and mentoring by Dehing et al. (2013).

The study is significant and different to previous research as it identifies how students learn about safety culture, it also identifies that a transformative experience is required for engineers to associate safety culture with their engineering identity. Furthermore, it captures what happens if a student is not exposed to these transformative experiences early in their engineering studies. It confirms that there is a discrepancy between the understanding of safety culture students gain from university and the safety culture understanding professional engineers have. The contributions and the impact of this research is significant as there is currently limited research on how safety culture is currently learnt in Australia. This study can be used to inform engineering education as not all students are graduating with the same understanding of safety and safety culture.

Limitations and Further Studies

This project was limited by the number of participants that were interviewed. The study was also limited to Engineers working in Western Australia that had studied at the University of Western Australia, further research into a larger scope of participants is recommended for future research.

Further studies branching off this study could investigate how safety culture is currently taught at university and what is the most effective way to teach it. One participant mentioned learning better from videos than PowerPoints, could Videos or VR could be used to teach safety in the future?

Conclusion

Safety culture is not a miracle, it is easy to have inflated expectations of what safety culture can achieve. Students learn about safety culture in university or work but require an emotionally transformative experience to associate it with their engineering identity. If a student does not have these transformative experiences, they are not able to relate to the content taught at university effectively which may hinder their learning.

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