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Engineering in a pandemic: the impact of remote working and learning on quality of work produced

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ABSTRACT

CONTEXT

COVID-19 has shocked the globe since December 2019, with unprecedented international and domestic travel restrictions and self-isolation policies enacted by governments around the world. With lockdown policies in place in hopes of preventing further spread of this disease, there has been a widespread transition into learning and working from home – causing a paradigm shift in traditional working and learning cultures.

PURPOSE OR GOAL

This study aims to investigate the effects of transitioning into remote learning and working on the quality of work produced, specifically by electrical and electronic engineers in Australia. The objective is to identify factors relating to an individual's ability to produce self-defined quality work and identify any emerging themes due to the change in learning and working environments.

APPROACH OR METHODOLOGY/METHODS

A total of six participants, consisting of five students and one senior engineer, was recruited and interviewed. Each brought their own unique perspective on the matter via semi-structured interviews where they were asked questions regarding their learning/working experience before and during remote learning/working. Defining quality working through the epistemology of practice, cooperative work and self-efficacy, and connectivity, the researchers investigated how the ability to produce quality work has been affected due to the change in learning/working environment.

OUTCOMES

The representative data indicated that feedback, open collaboration, and team rapport were the three key contributing factors to quality work during this transition to learning/working remotely. Feedback and collaboration contributed positively to quality work and a strong team rapport further augmented the individual's ability to produce quality work.

CONCLUSIONS/RECOMMENDATIONS/SUMMARY

This study provides an initial impression on the topic and invites further study to establish a deeper understanding behind the contributing factors towards quality work. Further studies into different engineering disciplines or a larger sample size to establish a larger data set is recommended to extract richer conclusions.

KEYWORDS

COVID-19, engineering practice, productivity, quality of work

Introduction

The COVID-19 pandemic has plagued the globe since December 2019. As of May 2021, there have been 162 million confirmed cases with approximately 3.4 million deaths worldwide (WHO, 2020). The COVID-19 pandemic has been a point of interest due to its abrupt and widespread impact, forcing extensive lockdown restrictions and forcing many to rapidly transition into working and learning remotely.

As professionals continue to transition into working remotely and communicating through digital platforms, it raised the question of the implications of doing so. Working from home brings comfort and increases productivity (Boland, De Smet, Palter, & Sanghvi, 2020), driven by the ability to be more flexible (Ganguly et al., 2020). However, the question of negative implications of working remotely has been raised, specifically whether communities would erode without physical interaction, whether planned and unplanned collaboration will be impaired, and whether mentorship and talent development will be reduced (Boland et al., 2020). For engineers and related technical professionals, reported challenges in the early stages of the pandemic include lower productivity related to: work-life conflict; fear of the pandemic; evolving regulations and safety requirements; technical challenges, decreased access to field or production sites, and increased complexity of scheduling of engineering activities (Ganguly et al., 2020; Persun, 2020).

Higher education students have also been impacted by the COVID-19 pandemic, with a rapid shift by universities to online education. Digital learning is convenient and may increase student interest and engagement (Kedraka & Kaltsidis, 2020). Increased student performance has been observed, due to changes in students' learning strategies (Mupenzi, Mude, & Baker, 2020). Negative implications of the move to remote learning include emotional implications and concern about future prospects (Aristovnik, Keržič, Ravšelj, Tomaževič, & Umek, 2020; Aucejo, French, Araya, & Zafar, 2020). Engineering education research has considered the impact of the COVID-19 pandemic on student experience and learning outcomes, including student performance in assessments (Gonzalez et al., 2020), and perceived learning effectiveness (Kapilan, Vidhya, & Gao, 2021).

This research explores the effects of transitioning to working and learning remotely through a digital platform on the quality of work produced by electrical and electronic engineers. Quality of work is a key component of the productivity of knowledge workers such as engineers, and is linked to organisational effectiveness and competitiveness (Drucker, 1999). For engineering students, quality of work is central to achievement of learning outcomes, academic performance and perceptions of employability (Rothwell, Herbert, & Rothwell, 2008). The "new normal" of the post COVID-19 era is likely to be characterised by ongoing digital transformation, working, learning, and teaching. Thus, is it important to consider the implications of these changes for engineering education and practice.

Research Objective

The question guiding this research is: What are the effects of transitioning into remote work and learning on the quality of work produced by electrical and electronic engineers in Australia?

Theoretical Framework

To define quality work and its contributing factors, literature relating to epistemology of practice, cooperative work and self-efficacy, and connectivity, was reviewed.

Epistemology of Practice

The epistemology of practice (Raelin, 2007) provides a link between an individual's ability to produce quality work and their ability to self-reflect and practice. This concept can be broken down into three main building blocks: tacit knowledge, critical reflection, and mastery. Tacit

knowledge is considered to be deep-rooted knowledge that surfaces when actions are considered intuitive (Shirley & Langan-Fox, 2016). In order to develop tacit knowledge, an individual would be required to accumulate experiences or to learn by doing (Raelin, 2007). Critical reflection plays a key role in developing tacit knowledge by making sense of an individual's personal practice (Kuhn, 1988), recognising that practitioners learn to perform through understanding the practical reasoning behind personal conditions derived from lived experiences (Yanow, 2004). Finally, mastery indicates a process of learning through practice and observation of experts to revise the cognitive patterns they have developed in response to changes in environmental cues (Schön, 1991). Expertise is developed by practicing in different contexts (Raelin, 2007).

Cooperation and Self-efficacy

Working cooperatively has been found to increase self-efficacy, that is the self-belief of an individual's ability to produce specific performance attainment (Carey & Forsyth, 2009). As a dynamic trait that changes over time, there are four external sources that contribute to shape an individual's self-efficacy: performance accomplishment, vicarious experiences, verbal persuasion, and physiological and psychological states (Bandura, 1986). A successful cooperative experience was found to enhance student's confidence in performing a variety of behaviours (Raelin et al., 2011), which provides a framework to investigate the effects of working cooperatively in a physical setting compared to a digital setting and whether that has any significant effects on an individual's ability to produce quality work.

Connectivity and Ideation

Björk and Magnusson (2009) provide a framework to investigate the effects of working remotely in isolation, finding that an individual's connection to a network (of information) and quality of innovative ideas generated had a strong relationship. As an individual's ability to generate new ideas is not dependent only on the individual but also on their position with respect to information flow (Allen, 1977), it's notable to investigate how the change in social context and interaction with other individuals due to this change in environment has affected the individual's knowledge (Spender, 1996). Despite the ability to connect with each other more than ever before through the world wide web, by transitioning to a remote working environment the individual may have lost sources of information flow. It is important to understand whether the connectivity and type of connectivity to a network of information plays a vital role in an engineer's daily life when working and/or learning to understand how the shift in working environment has affected an individual's ability to produce quality work.

Research Method

This study adopted a qualitative research approach using semi-structured interviews, facilitating a deeper understanding of the participant's opinions and attitudes relating to learning and working remotely, as human experiences have diverse qualities and meanings (Sullivan & Forrester, 2018).

Interview Protocol

Development of the interview protocol was informed by the three theoretical frameworks: epistemology of practice, cooperation and self-efficacy, and connectivity and ideation. The interview protocol comprised four sections, commencing with general questions that established the participants' experiences before and during remote working/learning and allowed the participant to reflect on their own definition of quality work. This was followed by questions relating to working under a supervisor or tutor; teamwork and self-efficacy, and participants' experiences of interaction and collaboration within teams. By investigating factors related to each theoretical framework before and during remote working and learning, the research aims to identify emerging themes and any other significant factors related to the

quality of work produced by an individual. The set of interview questions, complemented by additional probing questions, allowed flexibility depending on the participant's response, potentially providing a deeper understanding of each individual experience and perspective.

Participants

Using a criterion sampling approach (Miles & Huberman, 1994), electrical and electronic engineering students and professionals meeting the following criteria were invited to participate in this study.

1. Participants must have transitioned into remote working/learning between December 2019 to time of invitation to participate in the study (March 2021).
2. Participating students must be undertaking their penultimate or final year of their engineering studies, specialising in electrical and electronic engineering

A total of six participants, comprising five students undertaking their master's degree in engineering at a research intensive university in Australia and one senior electrical engineer working in industry, were recruited for the study. Four of five students transitioned to remote learning only as they were not engaged in engineering work during the time period. One student was working as a student engineer in addition to completing engineering coursework, and transitioned to remote work and remote learning. The senior engineer experienced transition from in-person to remote working in a full-time, supervisory capacity.

Data Collection and Analysis

Due to the relaxation of regulations surrounding COVID-19 at the time of data collection, participants were invited to attend the interview either in-person or online through a recorded Zoom™ meeting. With participant consent, interviews were audio recorded and then transcribed through a free to use online software called Otter.ai. Transcripts were reviewed and corrected by the researcher before seeking participant confirmation of the transcript.

An inductive thematic analysis approach was taken. The interview transcripts were thematically coded without a pre-existing coding framework or preconceptions of existing theory (Braun & Clarke, 2006). A multi-step analytic process comprising data familiarisation, generation of initial codes, and search for patterned responses, allowed themes to emerge from the data (Borrego, Douglas, & Amelink, 2009).

Findings

Three key themes were identified: feedback, open collaboration, and team rapport. An individual's ability to produce quality work was influenced by the level of feedback received. This was impacted by the ability to collaborate openly – to be able to bounce ideas off of colleagues and share different perspectives on a topic. Strong team rapport augmented these two factors and had a strong influence on an individual's ability to produce quality work.

Feedback

The change in working/learning environment resulting from the transition into remote work impacted the frequency, volume and timing of feedback received from a supervisor. The quality of feedback provided was found to remain mostly unchanged.

> *"I did receive constructive feedback both before and after. But I would say the frequency decreased a lot after COVID" – Participant 2.*

> *"I don't think it has changed the quality of work, … because for work I still get feedback, but it just might be later" – Participant 1.*

Barriers to feedback included challenges in reaching out and asking for help when working online. Another participant indicated that asking for help in-person would push the supervisor to answer the question rather than putting it to the back of their minds. The lack of physical gestures in the online environment formed a communication barrier, which impinged the ability to understand the supervisor leading to a negative impact on quality of work.

The senior engineer provided a supervisor's perspective stating the reduction in providing feedback had positive results.

> *"I think it (remote work) probably enhances quality // people don't get the opportunity to come to you to get the answer straightaway. They, you know, have to go find it for themselves, and when they find that answer for themselves, they've learned a lot more than they would by getting spoon fed the result" – Participant 6.*

Participant 3 perceived that an individual's ability to produce quality work is dependent on the relationship with the supervisor rather than the working/learning environment. Most participants described distant relationships with supervisors, and mentions of deep personalized feedback and task involvement was not present for any of the participants.

> *"It's a bit harder to ask for personalized feedback if you don't have any specific class or specific tutor or a lot of one-to-one time because the lecturers and tutors won't actually know who you are and how you're tracking personally" – Participant 3.*

The senior engineer felt that the digital barrier makes it difficult to understand underlying problems within a team. Junior engineers may struggle but no one will understand their struggles as only the result will be shown.

> *"It's very easy to think that they are simply not good at their job and it's hard to understand what sort of assistance is required" – Participant 6.*

The effects on feedback due to the changing work environment on an individual's ability to produce quality work appears to have deep rooted consequences, which may not immediately arise in the short-term. Restricting the intimacy between individuals results impacts feedback and affects the quality of work produced.

Open Collaboration

The change in working environment was found to have varied effects on the level and quality of collaboration. Participant 2 felt that remote working/learning made it easier to organise meetings as physical presence was not required. Collaborating with others did contribute towards higher quality work being produced, but it was independent of whether they were online or face-to-face. There were difficulties in collaborative efforts at first, however these were easily overcome.

> *"We got used to it. So just sending emails, pictures, or uploading it, or screen sharing. So, there are ways around it, definitely. Just a bit more troublesome" - Participant 3.*

Participant 4 provided an opposing perspective, finding it difficult to collaborate in a remote environment and identifying the online platform as a barrier to open collaboration. Participant 5 provided a similar perspective where the remote environment affected the quality of work, creating a 'hold-back' or deterrent to collaboration with other team members.

"Online, it's kinda like we are less or not that inviting, there's not that warm inviting environment coming in to share and stuff" – Participant 4.

The reliance on collaboration and its effects on quality of work produced appear to depend on the nature of work. Working collaboratively was effective when the task required more capacity – such as problem solving or large quantities of work. Participant 1 noted that the value of collaboration helped when she was unsure and needed clarification or explanation.

For work that did not require collaboration, interactions with others limited the amount of quality work that can be produced. Working individually was effective when the task required concentration. For some participants, the move to remote work provided relief from frequent disruption experienced in collaborative in-person environments.

"I can't recall how many times during the day I'd get 'hey, quickly…', and you know for me it was a very disruptive way as a manager to get any work done being in an open plan office everyone had access to" – Participant 6.

Collaboration between peers and with supervisors was seen as an important factor contributing to an individual's ability to produce quality work. However, in the new remote reality, some participants struggled to collaborate while others continued to thrive. Established routines were broken down, which made it difficult for some to continue producing quality work.

"I guess I was not so focused on work because I wasn't very, you know, like very high intensity because I was at home, so you didn't really – the environment didn't fit you know, the drive." – Participant 4.

The senior engineer provided insight into this juxtaposition, citing proactivity as a key influence. Despite a dire situation, there will be those who continue to thrive:

"Like an extension from Uni, it depends on whether you are proactive and strive for excellence. Because if you do the bare minimum you will end up average. So similar with junior engineers if they're tenacious they will succeed, whereas those who don't will probably struggle." – Participant 6.

Despite the challenges of transitioning to remote work, a common theme was the understanding that the task at hand must continue despite the situation. This manifested intentional collaborative efforts, for example Participant 1 was selective with who they worked with while Participant 4 created a digital space to continue having those working/studying and casual chatting spaces to replicate social warmth. The ability to be proactive, or the lack of, in collaborating with other individuals is therefore identified as a contributing factor towards an individual's ability to produce quality work.

Team Dynamic

The consensus regarding teamwork and quality of work produced was that working in a team, if done right, can result in higher quality work. However, this was conditional upon the team being engaged and aligned – meaning that everyone sought to complete their own tasks and were proactive in doing so.

All participants agreed that if the team were not engaged nor aligned, the team would become inefficient, resulting in poor communication and conflicting opinions, making it difficult to produce quality work within a team.

"There may be conflict in the opinions and there would be a hold back on some of the things that perhaps one person would like to do. Restrictions would be probably a lot if not communicated properly"- Participant 5.

Participant 2 provided insight to the impacts of the team on everyone's ability to produce quality work, understanding that it is not only dependent on how he worked but instead how everyone works together.

> *"I know that the performance of the team is dependent on how I work with everyone and how the people perform. So, it's less about just me but more about how everyone works together" – Participant 2.*

The same participant found that working/learning remotely made it difficult to establish rapport with the team, which may have affected his ability to produce quality work. In contrast, Participant 1 revealed that she already knew her team members, therefore a change in environment did not affect her team.

A strong contributing factor towards an individual's ability to produce quality work is their ability to communicate openly with others, whether working remotely or physically. However, the change in environment may impact the ability to establish rapport.

The senior engineer provides some insight into this finding. The change in working environment has established a barrier to supervisors truly understanding their team and how they work. Working remotely restricts the ability to mentor your team and junior engineers who struggle may continue to fall behind outside of an engineering environment.

> *"… it's about understanding your team, which can only really come from seeing how they work in person. I think that you can see how they work very quickly when you're working together. But by working remotely, that's probably a downfall to understanding your team member, what working style they are." – Participant 6.*

This supports the fact that rapport is a strong contributing factor towards the ability of an individual to produce quality work, tying into the two previous emerging themes of feedback and collaboration. With strong rapport between peers and supervisors, there is a greater likelihood to collaborate openly and receive feedback from each other – further enhancing knowledge and thus producing higher quality work.

Conclusion

This study aimed to develop an initial understanding of the implications that transitioning to remote work during the COVID-19 pandemic may have on the quality of work produced by electrical and electronic engineers, drawing on three theoretical frameworks: epistemology of practice, cooperative work and self-efficacy, and connectivity, to understand quality work.

Through a process of inductive analysis, three themes indicating the key contributing factors towards an individual's ability to produce quality work when transitioning to working/learning remotely emerged: feedback, open collaboration, and team rapport. The relative importance of the three factors on quality of work varied with the nature of the work. The role of the engineering environment in facilitating collaboration and rapport building for junior engineers and their supervisors was revealed.

The move to remote work during the COVID-19 pandemic has initiated a paradigm shift in working and learning culture. Going forward it is clear that routine and intentional touchpoints with colleagues to develop a deeper understanding of the task at hand and to develop a stronger relationship with one another is equally important when considering quality work. A concept applicable to both remote and physical work and education.

Limitations

With only 6 participants, consisting of 5 students and 1 senior engineer, the representative data set is limited. Further investigation with additional participants is recommended to reach saturation (Lincoln, Guba, & Pilotta, 1985) and refine findings (Tuckett, 2004). The

participants were undertaking a range of engineering work. This diversity may have influenced the emergence of themes.

Future Work

This study was able to provide an initial insight on the contributing factors to quality work for electrical and electronic engineers. To develop the understanding of how engineers can continue to produce high quality work as the working and learning culture shifts, further research is suggested. Refining this study by focusing on participants with similar industry backgrounds or work histories may assist with strengthening conclusions. Expansion of the study to additional engineering disciplines may result in new emerging themes to be found, further developing the understanding of how engineers can continue to produce quality work. It is also important to consider long-term impacts of this unique situation on engineering students and working professionals as the effects of career shock manifest over time (Akkermans, Richardson, & Kraimer, 2020).

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