Logic of internship learning in hybrid engineering workplace settings: A sociomaterial assemble of digital tools, humans & activities

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Abstract (200 words)

During the recent pandemic, established modes of organising internships in engineering were disrupted; Internships often transitioned into hybrid formats with extensive online activity. But, empirical research on the quality of learning in engineering during these exceptional circumstances is limited. This study therefore examines internship experiences among engineering undergraduates (N=39) in Singapore through semi-structured interviews conducted at two different time points. Thematic analysis revealed four challenges encountered by interns when access to engineering sites was disrupted. These included changes to processes of learning through the reorganisation of work routines requiring interns to adeptly utilize diverse technological tools and digital platforms for remote collaboration. Interns faced difficulties in gaining insights into the logic of engineering work through disrupted workflow. This was not helped when their learning experiences were also contingent upon the availability of meaningful work tasks. Finally, interns had to adapt to virtual and on-demand networking as a means of integrating into the engineering practice. Thus, the shift presented both challenges and opportunities for interns to learn about engineering in unprecedented ways. This research sheds light on how interns adapt during severe disruptions to engineering work environments, emphasizing the importance of considering the sociomaterial context for supporting interns in hybrid workplaces.

Introduction

In response to the increasing complexity of work, universities seek to complement their traditional focus on transmitting knowledge through established, in-house, activities by offering varied experiences, including experiential learning. A popular form of experiential learning is provided through internships. Through engaging in 'hands-on' and 'minds-on' activities such as managing challenging work tasks and developing solutions for firms, undergraduates are put in positions where they have to learn to apply production-relevant theories and frameworks taught in class to gain professionally relevant insights at the workplace. These immersive experiences are useful also in developing learners' awareness of the labour market and they provide the necessary work-setting exposure to facilitate informed career choices (Jackson & Wilton, 2016).

Within engineering education, the internship is a critical component of learning where learners gain first-hand experiences of engineering practices at production sites and where they encounter specialized kinds of know-how. Such early opportunities to engage in authentic engineering design work may help learners develop innovative design skills such as troubleshooting, needs identification, prototype creation, concept analysis and documentation (Irgens *et al*., 2015). Through internships, engineering undergraduates also have opportunities to gain access to a network of trusting relationships shaped by workplace norms to conscientiously contribute to the local engineering practices (Trevelyan, 2010, 2019).

However, with the recent COVID-19 pandemic, everyday work and internships were disrupted to various degrees. While firms tried to adapt and transition to hybrid ways of working that combine both online and in-person work arrangements, the consequences for internship can be regarded as a disruption that almost serves as a pseudo-experiment demonstrating what is likely to be lost in such a situation in terms of learning experiences. Focusing on everyday realities experienced by learners in their educational context—the hybrid engineering internship workplace during the pandemic–we aim to examine the losses and possible gains of engaging in engineering internship learning in hybrid work settings with a particular focus on understanding how learners interpret their learning during a severe disruption.

Notably, this problem of disruption of internship is interesting in its own right, and beyond the pandemic experience. Coping with such extraordinary circumstances may be informative about how learners cope with unusual situations. This article hence reports findings drawn from a larger study that examined engineering undergraduate internships from a sociomaterial perspective. In a nutshell, these participants were initially offered placements promising onsite full-time work with allowances. However, because the pandemic forced most companies to operate through telecommuting, they found themselves placed on hybrid internship work involving flexible work arrangements, such as spending alternate weeks working from home, reporting to the office a few times or once a week, and, for some interns, working in offices where co-workers were largely absent. As these circumstances have led to significant changes in the nature of internship experiences, it is important to examine their impact on the interns' learning and professional development. The following research question guides our study: What are the challenges faced by interns working and learning to become professional engineers when access to engineering workflow is disrupted?

The following section reviews key research on engineering internship as contexts of learning that underscore our contributions showing how learning about engineering occurs in disrupted work contexts. We next highlight from our interview data how materials, tools and technologies undergirded the learning of interns, and how these interns adapted to the challenges of engaging in engineering work, even as they had to cope with the unexpected hybrid arrangement of internship. Thus, the focus of our analyses is on the students' perspectives on these unforeseen challenges. Subsequently, we will discuss how these findings can be useful for learners to adapt to learning at the disrupted workplace, and the implications for workplace organisations and higher education institutions in considering new variants of internships.

Engineering internships and access to know-how

Roles and functions of internship learning

The education literature documents multiple advantages of engaging in internships in the field of engineering. These include learners professionalising themselves beyond conventional knowledge-related outcomes (Edwards, 2007; Fenwick & Edwards, 2013; Renganathan *et al.*, 2012; Virtanen & Tynjala, 2008). Significant perceived learning outcomes are also reported by learners in terms of gaining broad technical competencies and in developing generic skills such as those that emerge when learning to communicate in organisational settings (Najid *et al.*, 2012) and when engaging in teamwork activities (Lock *et al.*, 2009). In addition, there is also evidence suggesting engineering internships increase learners' motivation to continue their programme of study (Chesler *et al.*, 2013). However, our current understanding of engineering students' internship learning outcomes may be limited if based only on surveys that offer a general overview and are restricted by specific items in the questionnaire and issues of validity (Au Yeung et al., 1993; Parsons, Caylor & Simmons, 2005). Focus group type of qualitative studies, although valuable, may also lack insights into individual variations in learning experiences (Luk & Chan, 2022). Nevertheless, the positive effects of internships should not be taken for granted.

The complex nature of learning at the workplace requires a deeper consideration of how learning takes place at the engineering shopfloor during internship where learning can emerge in situations which are messy and unstructured, and where learning is opportunistic (Eraut, 2004). Not only is it important to consider the material and social environment at work that actively supports learning at the workplace (Billett, 2011; Barner et al., 2022), Hopwood (2014) argues for the importance of considering time, space, bodies and things constituting the texture of workplace practices. Social interactions at the workplace can significantly determine interns' learning experiences (Zehr & Korte, 2020), and the upshot for engineering undergraduates with exposure to textured professional engineering practices at the workplace and projects is a positive predictor of plans for engineering after graduation (Powers *et al.*, 2018). As a result, the training and material support mechanisms in place for interns (e.g., in terms of a clear internship plan, access to help, software, tools, mentors, and training with access to varied challenges) are critical for the successful completion of the internship (Fifolt & Searby, 2010). Evidence also points strongly towards supervisor support and supervisor mentoring as significant predictors of internship efficacy (McHugh, 2017). However, existing research exploring workplace support characteristics that promote learning, and how engineering professional navigate and engage with engineering practices, has primarily

focused on newcomer participation (Johri, 2012; Korte, 2018; Trevelyan, 2019). There is a significant dearth of research specifically examining how students enact learning during their internships within the engineering industry.

Learning from a sociomaterial perspective

In our view, the sociomaterial perspective is relevant for analysing the disruptions of established patterns of internship learning during the pandemic. Learning is a multidimensional process where knowledge emerges continuously in the context of situated action (Lave & Wenger, 1991, Johri & Old, 2011). People draw on their physical, and increasingly virtual, presence in a social setting, cultural background and experience, and on the material that is available to them to learn and to do knowledge work (Blacker, 1995; Orlikowski, 2002). To grasp the shift in learning due to the pandemic, we need to adopt an interpretive stance that allows us to comprehend the work of learning from a practice-based viewpoint. One avenue for building this understanding is the sociomaterial perspective (Johri, 2011, Sørensen, 2008; Suchman, 2007) which argues for equal foci on the social and the material context in which learning takes place. This is useful for encapsulating the meaning and mattering of materials in learning practices (Fenwick & Landri, 2012). With the material changing as it gets it meaning from practice, the dynamic entanglement of the social and the material constitutes the assemblage of learning. Applying this perspective to build an understanding of learning in engineering contexts, we can therefore emphasize the role of material and technology in engineering practices, joining fellow researchers to illustrate how material and social environments tie with activities to generate new practices in different domains (*Authors, 2022;* Barrett, Oborn, & Orlikowski, 2016; Paananen, 2020; Secules *et al.*, 2023).

The consequences of the pandemic, among other things, were that interns did not have access to the expected physical workplace in which interns typically immerse themselves in engineering practices through on-site presence. A key response in higher education to the pandemic in 2020 was that the global health crisis forced engineering educators to promote strategic efforts to improve classroom engagement and connection to better support students (McIntyre *et al.*, 2023; Nuankaew & Nuankaew, 2021). Universities and workplace organisations similarly sought ways to shift internships online, while attempting to maintain the educational and training quality of the experience. Digitization of access to and for work became the central modality of learning from work activities for students around the world (Lumpkin, 2020). Currently, there is a lack of empirical work analysing a) the specific features and usefulness of hybrid internships, which represent a combination of online and in-person for students, or b) their effectiveness in contributing to positive educational outcomes for graduates (Hora *et al.*, 2021). In this study, we aim to fill these gaps by generating new evidence about how hybrid internship engineering co-determined learning at the workplace amidst the pandemic by illuminating the tensions occurring as stakeholders of internships adapted traditional ways of engineering training and learning to ways of learning in hybrid work context.

Context

Participants

This study is part of a larger research project investigating undergraduate internship learning from a sociomaterial perspective. Researchers sent email invitations to all third-year engineering undergraduate students before the start of the internship through the career affairs office. These interns were mainly recruited from the various schools of engineering ranging from mechanical, electrical, materials to computer engineering. Interns have also completed core theoretical and practical engineering modules prior to their internship placement and would have completed engineering modules ranging from mechanic and electrical design to software development. Informed written consent was also obtained from the interns to participate in this study. Penultimate year engineering undergraduate interns (N=39, 31 males & 8 females) agreed to participate in semi-structured interviews during the second and fourth month of their internship placement during the pandemic year of 2021. Work mode for interns participating in this research project mostly was hybrid in format. Names used in section of results are pseudonyms to ensure confidentiality and anonymity of research participants.

Data collection

During the interviews of about an hour duration each time, the questions focused on learner's motivations for internship, on-boarding processes in the workplace, the nature of work performed at the workplace, tools used during their work, as well as challenges encountered and how they coped with these challenges. Critical within these interviews was the elicitation of experiences of the intern as a newcomer at the workplace, explication of learning episodes at work and access to significant work practices. We conducted 78 interviews in total and the interviews were audio recorded and transcribed verbatim.

Data Analysis

For the excerpts used in this manuscript, the first stage of analysis entailed a thorough immersion of researchers within the data, which included listening to recordings of the interviews, readings and re-readings of transcribed interviews (Green et al., 2007). This was part of the inductive analysis for coding and theme development that valued the experiential orientation of interns as they described their internship experience. Salient at this stage was noting the myriad technologies and types of engineering workflow reported by interns as embedded within the workplace. To immerse more deeply in the data, researchers identified and labelled segments of interest and relevance within the dataset for explicating challenges experienced by the interns. This was an iterative process necessary for making sense of data to develop insights into the sociomateriality of challenges described.

With initial codes such as 'dealing with interpersonal challenges', 'gaining work autonomy', 'time management', 'learning about the industry' written to capture emerging through data exploration rather than being predetermined, our subjective and interpretative perspectives (Braun & Clarke, 2012) led to the second stage of analysis focused on the material and engineering tools/objects across work events and activities as described by research participants. In doing so, we adopted the point of view of the intern as a reference which aimed to document a specific way of making knowledge emerge (Dieumegard *et al.*, 2019). Rich descriptive accounts of subjects were written and discussed during team research meetings, using references to the literature to support the analysis. In doing so, intern accounts of learning were categorised into four different types, namely interns who had completed internship with developmental opportunities leading to affirmation of engineering as a profession after graduation, interns who had completed internship with developmental opportunities but not leading to the affirmation of engineering as a future profession, interns who had completed internship with limited developmental opportunities and no immediate desire to continue in the

engineering profession, and the final category of interns who completed their internship but could only offer accounts of learning described as insignificant, low-skilled work activities over durations of interviews. This data reduction was necessary for researchers to advance to the next stage of pattern formation and identification, where researchers subsequently focused on episodes of internship learning descriptions to code and cluster patterned meaning as relevant and guided by the research question.

The relationships of the codes and identified themes on the impact of challenges on internship learning are described in Figure 1 and facilitated research team members to analyse across the dataset for repeated patterns of meaning. Research team members discussed emergent meanings about the challenges along the timeline of workflow and over different types of work tasks as revealed by research participants during the interviews. Reconstructing the dynamics of the intern's coupling of knowledge, enactment and emotions within their dynamic work environment, the next section presents findings of how the ensemble of digital tools, humans and work activities imbricated with the learning experiences of the interns at the hybrid internship workplace.

<<<Insert Figure 1 about here>>>

Findings

Four themes emerged from the analysis of the interviews that describe the unique challenges encountered by interns as they navigated a mix of remote and in-office work environments. Within the hybrid arrangement of engineering internship, challenges included

- Changes to processes of learning through the reorganisation of work routines: Disruption to worksite access during pandemic necessitated creative adaptions to workplace practices for interns to continue their work and contribute to engineering projects despite the physical constraints.
- Difficulties in gaining insights into the logic of engineering work through imposed changes: When interns encountered challenges, they had to delve deeper into problem-solving, sense making of engineering processes albeit now in disrupted work environments which were not always transparent.
- Availability of meaningful work tasks: Quality and availability of relevant work tasks played a role in shaping interns' learning experience during these exceptional circumstances. When provided with purposeful tasks, interns reported being able to develop skills and knowledge in the engineering domain. This contrasted with situations in which they were given limited access to meaningful tasks which, in turn, hindered their ability to leverage the learning potential of their internship.
- Adapting to virtual and on-demand networking as a means of integrating into engineering practice: Faced with challenges in physical interactions due to the hybrid arrangement, interns adapted by creating virtual connections with their colleagues and supervisors. Through online communication for meetings, reporting, submission of data, interns actively integrated themselves into the engineering space.

The findings are presented below weave the words of the interns so that their voices may be heard.

Changes to processes of learning through the reorganisation of work routines

With the physical access to work environment disrupted by restrictions imposed by the pandemic, it was not surprising that the engineering workflow was disrupted. Workplace organisations and interns had to resolve the challenge by adapting engineering work

production practices into hybrid sociomaterial processes (Johri & Olds, 2011). Mechanical engineering interns reported having difficulties accessing physical worksites, such as warehouses to observe manufacturing processes, laboratories and other facilities. The resolution of such dilemmas implied that interns began to rely on video live feeds of manufacturing processes to identify engineering workflow for following design improvement works. When inspection of refurbished aircrafts was disrupted, aviation engineering intern Gary had to schedule new reporting routines to permit his technicians access for the related tasks and reporting back to him via email the progress of work before Gary could subsequently apply for permission from the company to be physically on-site to inspect the aircraft.

A few mechanical engineering interns reported how on-site engineering laboratory work became a complex protocol of co-ordination, where only half of laboratory staff members could be present each time at the workplace. As a result, interns in the same laboratory had to rely on work schedules which gave them access to the test laboratory on even weeks to set up their experiments. These interns would then ask their fellow interns scheduled for lab work on odd weeks to double check that their experiments were running as planned. The alternating access to space at the work site drew interns into a collective for ensuring that the experiments were not disrupted. As a result, experimentation work in the laboratory became a collective activity characterized by distributed knowledge production as interns stand-in to monitor and update each other's experiment progress. Critically, during these hybrid internship period, the workflow constituted solutions to the difficulties the engineering community at the shopfloor were facing during the pandemic; that in order for the internship to continue, the workflow was modified by both supervisors and taken up by the interns in order to keep the internship going.

Software engineering interns reported how they adapted by first setting `the variables and run the test with the data going to their phones`[1] and interns would stay home to `analyse data and call colleagues over the phone for help` during analysis. Engineering interns placed in cybersecurity, robotics and bioinformatics laboratories reported using material artefacts such as cyberinfrastructure, open-source codes, YouTube videos as platforms to gain access to computational knowledge relevant for further coding purposes. These technologies were powerful at connecting interns to a large virtual community of users to seek solutions for solving computational engineering problems when seeking immediate help by walking over directly to supervisors or colleagues at the workplace was not possible due to remote work arrangements. By entangling themselves with the virtual community for knowledge production and translation back to their engineering work, coding issues faced by the interns during their internships are similar to how professional software engineers make do with whatever resources are available to develop work practices that span geographic dispersion (Johri, 2011). The specific conditions under the pandemic in this sense created a context in which it became natural to engage with colleagues in productive ways which mimic regular work practices for this particular group.

Workplace supervisors emerged as an important member in the entanglement of social and material interactions as interns adapted to disrupted work routines. By co-ordinating their interactions with interns through `weekly meetings over zoom`, followed by meeting up at the office at least once a week as well as assigning a day for intern to `work on their`

[1] `Text in Courier New font is original data extracted from the transcriptions of intern interviews.`

own, prepare materials at home, prepare for assigned work tasks, work supervisors adapted by focusing solely on hands-on work together with the interns at the shared material worksite when both were rostered to return to the workplace. Expectations were subsequently placed upon interns to complete material work at home including documentation, preparing instructions, replying emails and workplace supervisors would rely on digital technologies to monitor the work of interns by checking if completed paper work was uploaded to knowledge management platforms such as Microsoft Sharepoint. For electrical engineering intern Abram, disruption of workflow due to the pandemic resulted in hectic days of site inspections followed by working on inspection reports from home:

> We settle the site inspection first then when I go home, I do the reports. Three to four site inspection a day but my project engineer has a car so we have the ease of mobility around.

Even as work practices were adapted by both interns and work supervisors in time and space, generic engineering skills such as attention to detail to ensure accuracy and quality in one's work were imparted to learners when they are closely mentored by their workplace supervisors. Through conversations about seeing the details, and how electrical engineers need to build trust between their work output and their clients, Abram realised the importance of quality assurance in engineering work:

> The main project engineer tagged with me is like a mentor. He guides me along on what to do, how to present findings how to recommend rectification works. He explained why he gave me reports to write (paperwork) after site visits. This is job is really about the details, it all takes one small mistake and everything goes wrong. So one of my project engineering explained to me 'if you can't get your paper work right, what makes you think people will trust you to turn on their electrical switchboard' the expectation upon me to become more meticulous has definitely grown in me during this whole internship period.

For interns who were tasked with design improvement projects, they had to adapt testing workflow to the hybrid work arrangement by first planning for experiments, creating hypotheses and identifying specific variables for testing, at home for a week, following by setting up of the experiment and doing all the testing during the next five days. This adapted work arrangement enabled mechanical engineering intern David to learn about improvisation for productive engineering work from his supervisor:

> Usually, we physically dismantle the iron where actual steps require me to list down all the components' parts and swap one by one for testing. But my supervisor shared the actual component list with me so I read through it. But it is impossible to swap all the small, small components, so my supervisor and I narrow down the clothes iron into (major) parts. So we swap big components such as the whole boiling system instead of just the pumps. My supervisor told me to do that as it helps save time and it is too much hassle and time to swap every part. Plus with this work from home stuff,

> we only have five days to do all our testing, so we lower down our focus onto the specific parts.

The interactive use of the actual component list by the supervisor and interns resulted in improvisation for designing time-saving experiments and novel ideas pertaining to experimental test designs was enacted in the intern David's work processes during the hybrid internship period. The spontaneous planning based upon the material list, detailing the individual components of the clothes iron, was an instance of improvisation work by engineers as they responded to emerging challenges (time for experimentation) and opportunities to increase testing efficiency in their work (Miner, Bassoff, & Moorman, 2001). The order of swapping out components, in accordance with the component list that had seemed sensible before the pandemic, was no longer efficient given the hybrid work arrangement. Intern together with his supervisor re-interpreted the material list of engineering components resulting in an adaptation of engineering work processes for continuity of work. Crucially, this required the supervisor to share important information with interns to justify how typical engineering work processes were adapted, and significant features of emergent learning become apparent when intern connected the established traditional ways of engineering work with adapted workflow together his supervisor. The collective engagement in executing the workflow, combined with the interns' adaptation to the altered work process, led to his decision to place less emphasis on specific components.

Difficulties in gaining insights into the logic of engineering work through disrupted workflow:

With access to the traditional engineering workplace disrupted, the logic of engineering work became less visible for the interns with limited interaction with tools and humans at the engineering shopfloors. Despite the disrupted workflows imposing changes in how engineering work was performed, most interns reported encountering and solving workplace challenges as the means for learning the logic of engineering work. Within the hybrid arrangement of work for interns, interns revealed they had to identify the root cause of the engineering problem and seek out resources, either through manuals, searching through the internet, or by asking colleagues over Whatsapp for advice, in order to solve the problems without disrupting the already irregular workflow at the engineering shopfloor. This is especially salient when Brian, working as a quality assurance engineering intern, described the identification of a problem as the starting point for his learning and the subsequent entanglement with other colleagues and workflow of the company:

> some issues like short-circuit, or when the display is not working, there is a very systematic way in identifying the issue, and also to liaise with a lot of people from different backgrounds to find out what really is the issue, and also trying to manage in a way that the supply chain is working and is not disrupted because of this issue, So, a lot of things you navigate from this particular role (as a quality assurance engineering intern).

Significant in the above excerpt is how intern Brian had identified himself in a job role that guided him to first identify an engineering issue and to delve deeper into the problem by liasing with people related to the issue while ensuring that the supply chain is not broken. As Schatzki (2002) describes professional practices as shaped by rules, forms of understanding and intentions, it was only when Brian was in the 'particular role' of a quality assurance

intern he could seek to align problem solving on site in relation to the larger engineering supply chain work flow.

In the process of solving workplace challenges, interns engaged in improvisational work for dealing with practical engineering problems at the workplace related to system design, experimental set-ups, and re-assembling of dismantled machines. For example, when intern Hattie was tasked to install a data collection chamber, which he had not encountered before at the university, he first had to understand how data loggers work followed by `figuring out` how to attach the data collection device to a physical chamber.

> So, firstly figuring out how they work. And then secondly figuring out a way where we could sort of install them in the chamber so that we can collect the measurements. And then figuring out how to extract the data because uh… some of them do not have a built in data loggers. So that, there has to be, we have to connect them to another external data logger or something like that. So yea, that's one thing where I, I enjoyed it when I finally able to do it…there were manuals, where I could sort of refer to them…but the manuals obviously do not have everything. Second was that there were… the previous interns work…i had work (with) to whatever material they had left & extract whatever I could.

This contrasted with how undergraduates have been reported to engage in engineering learning in the classroom or laboratory as learning something that 'practicing engineers are assumed to already know' (Feisel & Rosa, 2005, p. 121). In the case of Hattie above, there was no expectation for him to know how to connect the data logger to the chamber, in fact, he had to work with `whatever material` was available for completing the work task. In this sense, the disruption seems to have led to innovation in learning at the workplace.

Time was a constraint for the engineering interns as most mentioned about the lack of it to `finish all our test`. This was expressively described by David:

> We cannot finish within the week. For example when you heat up the iron, you need time for it cool down, need two hours but we don't have two hours for it to cool so we will always push the boundaries, like cool it down instead for 20 minutes. There is this incident where I forgot the ironing container was pressured and with only 20 minutes (of cooling) I went to open it and the whole thing shot up. I was not injured but it could have been a mishap. From then on, I become very careful and understand there needs to be a safety feature where we (first) release pressure bit by bit before we pour water inside to further cool the iron. So, from there I learn, some things you cannot push it too far.

Worrying was the inherent danger lurking behind the lack of time for interns and coupled with limited knowledge (safety feature of devices) of how to optimise

experiments quickly, accidents may happen as described by David above. With safety linked closely with the expert and tacit knowledge of the professional community (Gheraidi & Nicolini, 2002), intern was learning local awareness of what was going on in his everyday work activity and ultimately reporting safety as dealing with an ambiguous situation and learning `not to push it too far` in order to achieve safety as a practical accomplishment at his workplace.

Availability of meaningful work tasks:

Perhaps to a large extent unknown to the interns, were the details of exactly how the pandemic had affected businesses and that this greatly disrupted also the volume of work available for interns at the engineering shop floor. Interns reported engaging in routine low-level tasks that did not contribute to their professional learning and feeling discouraged. This was articulated by mechanical engineering intern Adam, who was working in a small-medium enterprise with about 40 employees. Adam mentioned about doing menial work of cleaning glass tubings as part of equipment preparation for senior staff and the lack of learning opportunities due to less contracts received by the firm. Due to budget constraints, there were also companies that could only offer learning opportunities with no allowance, Sam, an intern in the hybrid work arrangement, mentioned how it was his personal interest in robotics that sustained his engagement in the robotics laboratory for his internship:

> `I approached the robotics lab for an internship position…They said cannot apply for the salary…but I want to do robotics stuff and I want to learn. Everyday I have three activities and only when I can figure out how to solve the activities I moved on to the next. From writing the programming to move a robotic arm to picking up selected objects to moving the objects to designated areas. I stay back to work on the projects.`

In work environments disrupted by the pandemic, access to knowledge was disrupted and interns alongside their workplace colleagues adapted their practices at the individual level to enact engineering practices in flexible ways within the larger structural workplace environment. Employing deliberate strategies to overcome challenges imposed by the pandemic, interns learnt the logic of engineering work. Yet, all these were only possible contingent on the nature of the work, the relation of the interns to the workplace and the nature of practice. As reported in this subsection, there were instances where work was not plentiful or easily adapted for hybrid internship learning, neither were there sufficient funds to support internship learning at the workplace.

Adapting to virtual and on-demand networking as a means of integrating into engineering practice:

Networking opportunities for socialising interns into the organisation often available through engagement in formal onboarding programmes, participating in team meetings as well as through informal ways such as spontaneous chats with colleagues along the office corridor,

had all but vanished during the pandemic. Networking opportunities, forming a crucial part of internship learning (Authors, 2022), instead became an improvisation of known communication patterns for the interns during their hybrid internships. Using telecommunication tools, interns experimented and used different types of active online communication methods with their colleagues and supervisors ranging from emails to Microsoft team chats and Zoom video calls, when they were working from home. While these methods were mostly successful for tasks completion, most interns still reported a clear preference for returning to the workplace. Reasons included from being more motivated when one is at the workplace to opportunities to `level up on soft skills` were mentioned by interns.

Unfortunately, it was observed that on occasions when interns returned to the worksite, building relations with fellow colleagues at the workplace continued to be limited as many of the permanent staff were still working from home. Networking opportunities were restricted, and one needed to improvise by going for lunch with fellow colleagues who `happened to be there` and `buying breakfast` for the team that `is in the office that day`.

Finally, it is obvious that weak mentorship from workplace supervisors can isolate interns from learning the myriad of engineering practices. As mentioned by Ginny working on a software engineering project during her internship:

> what I feel from our limited supervisor-intern interaction is that I am not able to meet other interns, I don't really know what work goes on in the company and not getting to see what the department does. When I go down to the office (to collect equipment) I do see people around but there's no one else in the interns' room. This was like reading the documentation by myself at home when I first started the internship, I don't understand a single thing.

Without the formal introduction by the work supervisors, intern Ginny reported having no opportunity to network further with other colleagues of the firm and she felt isolated within her project. Hence, she had to rely on the interaction with her supervisor who was mostly available online for consultations related to the `technical aspects` of the project.

In contrast, for workplace supervisor Ben, supervising intern Luna at an electrical engineering firm, made explicit efforts to expand the network of the intern by assigning her to non-engineering tasks such as organising team bonding events for the department when pandemic restrictions were removed partially for enabling more employees to return to the workplace. While these forms of socialisation can be risky as interns may not be familiar with the protocols of doing non-engineering related work functions, these networking opportunities being spontaneous in nature, while required by the work context, and yet not necessarily within the control of the intern, can be useful for interns to develop trust with their fellow

colleagues working in the same team and build enhanced awareness of their needs and expectations through interactions in informal settings (Handfield & Bechtel, 2002). For Luna, these socialisation tactics employed by her workplace supervisor intertwined and mutually reinforced learning at the workplace as they were occasions for network building, as well as information/ feedback-seeking (Van Kleef, Steen & Schott, 2019). It is no wonder Luna commented that her supervisor would often use such informal occasions to remind her of the importance of punctuality and the need to actively communicate her accomplishments in meetings, rather than remaining silent about her contributions.

Discussion

The findings above unveiled the entanglement of sociomateriality that matters for internship learning amidst the pandemic. When procedural implementation of work activities was not possible at the engineering worksites, workplace organisations adapted work over multiple spaces (Paananen, 2020), resulting in changes to processes of learning through the reorganisation of engineering work processes such as through design experimentation, quality control assessment being adapted into a blended and distributed format. The first finding alerts us to the role of the workplace supervisors as part of the entanglement in aligning material resources of work activities at the engineering shopfloor for their interns and ordering them into resources for continuing work activities at the homes of the interns, a site of emergent learning (Reich, Rooneessy & Hopwood, 2017). Interweaving the work of interns with telecommunication for reporting progress, the social (experiments and electrical testing being enacted) and material elements (e.g. the ironing tool, electrical dashboards, technological components) are combined as part of the engineering practice embracing the full complexity of the final artefact (e.g. client agreeing to turn on the electrical power supply, electrical equipment approved as adhering to standards), our findings offer a contemporary view of practice (Orlikowski & Scott, 2008).

Our second finding revealed interns struggled to grasp the logic of engineering work due to disrupted engineering workflow, yet learning was evident as they encountered and attempted to overcome workplace challenges. Critically, where the combination of social and material elements that typically allowed engineering workflow to function properly ceases to work, this generated a series of intersecting dynamics for interns to respond to. In responding to challenges, such as not understanding why components were not working, or data collection anomalies, interns improvised, adjusted variables and consulted with colleagues for problem-solving. These are components of the sociomaterial setup of the engineers' day-to-day work and constitute parts of expertise development (Johri, 2022). Such enactment of improvisation, testing, and design should not be misconstrued as opportunistically manipulating knowledge or technology to acquire more favourable outcomes, but rather is a reflection of the selection of strategic actions before the experimental situation aligned closely with the broader interest of the organisation. This embodies the operative hypothesis of the practising engineer (Styhre *et al.*, 2012), therefore highlighting the intricate interplay of material and social actors constituting contemporary engineering work.

With hybrid work settings adapted to structure engineering internships for continuity of work, our findings demonstrate how undergraduates were challenged to take greater responsibility for their learning in hybrid sociomaterial learning environments. This arrangement not only presents challenges but also unique opportunities for interns to engage with the engineering profession in novel ways. Theoretically, this adaptation aligns with the concept of learners becoming directors as well as actors in their own life/career dramas (Arthur *et al*., 1999) as they navigate the path to becoming professional engineers in unconventional circumstances, demonstrating initiative in addressing workplace dilemmas.

Increasingly, employees are accustomed to working productively from home and with employers benefitting from cost savings associated with remote work, hybrid work is likely here to stay. This may be seen as a general lesson of what happened during the pandemic. We must however be keenly aware of unintended consequences for internships, such as availability of meaningful work tasks and ability of interns to adapt to visual and on-demand networking as a means of integrating into the engineering practice as highlighted in our third and last findings. Interns can feel discouraged, lost in an abstract scheme of work, forming a smaller network of colleagues, and the missed opportunities for learning informally from fellow colleagues at the worksite that may impact the overall socialisation of interns. When the conventional physical environment, including when sociomaterial artefacts such as tools, routines and shared presence are disrupted, the shared material and social environment considered essential to achieve theoretical, practical skill and attitudes for gaining vocational competencies (Hiim, 2020) may indeed be at risk.

Conclusion

This study sought to understand the challenges encountered by engineering interns during a period of disrupted access to work practices. To this end, our study highlights the significant impact of the pandemic on the structure of internships, necessitating a transition to hybrid learning environments. This has led to a reconfiguration of engineering work processes, with workplace organisations and supervisors playing a crucial role in aligning resources and facilitating work continuity. This adaptation has presented both challenges and opportunities for interns, requiring them to take greater responsibility for their learning and engage in improvisation in response to disrupted workflows. By recognizing the sociomaterial nature of engineering work and learning, we can better support interns as they develop the skills and understanding necessary to navigate the complexities of engineering practices.

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