Learning From Incidents And Implementing Action: Exploring Expectations And Contradictions In The Energy Sector

Thesis

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Link(s) to article on publisher’s website:
http://dx.doi.org/doi:10.21954/ou.ro.00010f9d

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Learning from incidents and implementing action: Exploring expectations and contradictions in the energy sector

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Thesis submitted to The Open University

for the degree of Doctor of Philosophy in Educational Technology

Funding for this thesis was provided by the Energy Institute

Institute of Educational Technology (IET)

The Open University

Sept. 2019
Abstract

Learning from incidents (LFI) is an organisational learning process whereby accidents or near-misses are used to stimulate learning in order to prevent similar events in the future. Prior research has demonstrated that an important step in LFI is the distribution of incident summaries to enable individuals, teams, networks and organisations to learn. These summaries should in theory support vicarious learning for those not directly involved in the original event. This thesis investigates the following major gaps in LFI literature: the role of networks in LFI, what practitioners perceive to be successful learning in the context of LFI, beneficial practices in LFI, and current barriers that prevent successful LFI.

These gaps were investigated through a mixed method multi-case study design across three large energy organisations. The research explored the responses of over 160 participants to two surveys, and 45 semi-structured interviews.

The first key finding, related to network use in LFI, was that, within each organisation, the structure of both formal and informal networks was dependent on contextual factors, such as geographical dispersal of workers. Within each of the organisations, employees use their networks in similar ways: to exchange information and to understand the connection between an incident and a worker’s own practice.

The second key finding addressed the gap on what practitioners perceive to be successful learning through identifying a taxonomy of 24 learning objectives associated with LFI. The taxonomy included observable outcomes, such as changes in best practice, and included objectives necessary to foster an effective learning process, such as open communication.

A finding related to beneficial practices in LFI was the identification of a unique approach to LFI within each of the three organisations: one organisation used technology to support communication related to LFI; another held safety events that considered multiple incidents related to a single process; the third created opportunities for workers from different teams to meet and discuss incidents through a variety of inter-departmental meetings.

The final key finding of this research was the deduction of four contradictions observed across the three organisations that created barriers to learning: a lack of differentiation between safety and learning; perceived irrelevance of some incident alerts; inconsistent pedagogical support for learning; and an inability to differentiate between incidents that had occurred due to the probabilistic nature of events, or a lack of learning.
Acknowledgements

I would like to thank the Open University and the Energy Institute making this work possible and for all the support they have provided to me in the past three years. I would also like to thank Prof. Regina Mulder and Prof. Mark Fenton O’Creevy for the time they took to read through my thesis and to facilitate a challenging and thought-provoking viva.

The rest of the people I would like to thank are those individuals who have been with me throughout my PhD journey. My academic supervisors, Allison Littlejohn and Bart Rienties, have been a source of much joy, and at times heated discussion. I certainly appreciate that those heated discussions have challenged me and enabled me grow as both a researcher and a person. The approach to problems that you both helped me cultivate will be of great benefit wherever the windy walks of life may take me. I am equally grateful for the non-academic support; not everyone can enjoy a drink with their supervisor, but I am happy there have been many such occasions for the three of us.

I would also like to thank Stuart King, Robin Bryden, Andrea Parker, Matthew Lawrie, and Razif Yusof. All of you have provided me with excellent advice and guidance, especially when reflecting upon my results and why they matter. I am also thankful to the organisations who contributed to this thesis, especially those who supported and participated in the research. I hope its results will be of use to the sector and make the time and resources you so kindly lent me worthwhile.

Thanks are due to the whole of the PhD community in IET. The PhD journey has ups and downs, but I have been so fortunate to undertake these trials, tribulations, and triumphs with such an amazing group. The future is an uncertain entity, but I know that we will all find the right paths to walk down.

To my parents I will always be eternally grateful. My life to this point has definitely been an adventure, with a lot of unexpected twists and turns. I have been able to take chances and pursue what I love thanks only to the support and love that they have given me throughout my life. I know that no matter what happens they will always be there for me, which has been a comfort at several of the more difficult times during this PhD journey! Andy and Julia, thank you both for listening and encouraging.

Finally, to my partner Sofia, you have been there every day to both comfort and celebrate. I know that my PhD has at times been almost as emotional for you as for me, and you deserve a lot of credit for my completion. Thank you from the bottom of my heart.
Declaration of Authorship

I declare that the work contained within this thesis is my own. Several sections of this thesis have been edited and published, or are being prepared for publication. Publications to date and articles currently being prepared are listed below.

While all publications have multiple authors, I have been responsible for the research design, data collection, data analysis, and write-up of the work in this thesis. My academic supervisors (Professor Allison Littlejohn and Professor Bart Rienties) have contributed through reflection and suggestion at all stages of research. My industrial supervisors (Mr. Stuart King and Dr. Robin Bryden) contributed through their suggestions at our monthly meetings and through comments on draft copies of manuscripts.

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‘Mistakes are the portals of discovery.’

James Joyce
1 Introduction

Learning from incidents (LFI) is a topic that I value greatly on a personal level. From 2008 to 2012 I lived in Southern Japan in a prefecture called Ehime. On the 11th March 2011 Northern Japan experienced a massive tsunami-inducing earthquake, inflicting tremendous harm and damaging the Fukushima Daiichi reactor, making global news. I was fortunate not to be directly affected by the results of the earthquake nor the tsunami, but I saw and felt the shock and panic of the whole nation in the following days. The level of background radiation in most of the country did not rise to dangerous levels, and it was only the immediate area around the nuclear power plant that became severely irradiated. However, I will never forget staying in a hotel in Fukushima a year later that had a Geiger counter at reception so guests could monitor the background radiation level and be reassured of their safety. While the incident was caused by one of the most powerful earthquakes in history, later reports suggested that preparations based on past events could have been implemented that would have drastically reduced the negative consequences of the event ("Japan says Fukushima disaster was ‘man-made,’" 2012). These experiences have taught me the value in learning from the past to prevent future disasters.

In general, the topic of LFI has seen an increase in societal interest in the past few years. The best-selling book Black Box Thinking (Syed, 2015) presents examples from a number of organisations that have used data from past incidents to improve processes. The book presents a compelling case for the open exploration of past incidents by describing the experiences of a husband working in the aviation industry, reputed as having an excellent system for LFI (Le Coze, 2013; Sanne, 2008), when his wife passes away in a hospital, where support for LFI is seen to be less effective (Macrae, 2015). From examination of labour statistics, there also appears to be compelling evidence that the number of injuries and deaths in workplaces is too high and needs to be reduced by learning from the past. In the EU-28 countries there were a total of 3,876 deaths in the workplace in 2015 ("Accidents at Work Statistics - Statistics Explained," 2018). A similar story is seen across the world, as evidenced by the 5,147 workplace deaths in the US in 2017 ("National census of fatal occupational injuries in 2017," 2018). As statistical models predict that there is a 50% probability of a large-scale disaster occurring again in the next 10-20 years (Wheatley, Sovacool, & Sornette, 2017), there is a moral imperative to better understand how organisations can learn effectively from the past to prevent injuries and even deaths.
1.1 Background

LFI is defined as a process where incidents are used as stimuli for learning with the aim to prevent accidents in the future (Drupsteen & Guldenmund, 2014; Lukic, Margaryan, & Littlejohn, 2010). In the literature, there is debate about the definition of an incident, such as whether everyday events or positive examples can be used for LFI (Sanne, 2012; Walker, 2017). In this thesis, a definition of an incident in line with educational literature was adopted: an unexpected event that challenges the models of the world previously held by those involved (Dewey, 1910).

As an organisational form of learning, the phases of LFI have been mapped out by two research groups. The first research group, Littlejohn, Margaryan, Vojt, and Lukic (2017), suggested that there are six phases in the LFI process: reporting an incident, investigating, developing an incident alert, disseminating that alert, reflecting on how the incident alert applies to various contexts, and implementing actions. This process is similar to the cycle of experiential learning proposed by Kolb (1984). An incident acts as an unexpected event, prompting reflection by an organisation through an investigation, organisational models are updated in line with new understanding from reflection on the incident, which are then tested by making changes to the way work is conducted. However, the LFI process has an individual cycle of experiential learning nested within this organisational cycle. Humans are able to learn vicariously through the experiences of others (Biesta & Burbules, 2003). LFI therefore also aims to prompt learning in individuals through dissemination of incident alerts. In this case, workers receiving an incident alert have the opportunity to reflect on what parts of this incident have parallels in their own context, and use the insights of the investigation to improve their own work (Snowden, 2002).

The second team of researchers, Drupsteen, Groeneweg, and Zwetsloot (2013), proposed a similar model consisting of four main stages: reporting, investigating, communicating, and evaluating. While the reflection and contextualisation of incident-information was not explicit in this model as in Littlejohn et al.’s (2017), the model included the additional step of evaluating the changes resulting from incident investigations. Evaluating learning strategies and their results is an important part of regulating learning processes (Zimmerman, 2002), and so is likely to be an important additional step in LFI.

Research to date has focused on several themes within LFI. The reporting phase has been the subject of several studies investigating why people may not engage in the LFI process at all. Results have identified several reasons not to report an incident: fear of repercussions (Haw, Stubbs, & Dickens, 2014; Leicher, Mulder, & Bauer, 2013); not perceiving an incident as an opportunity to learn (Gilbey, Tani, & Tsui, 2016; Rossignol, 2015); or inability to report an incident
when it occurred and forgetting to do so later (Dillman, Voges, & Robertson, 2011). Another area that has been the focus for several studies is how investigations are conducted, ranging from the comparison of different incident investigation techniques (Lundberg, Rollenhagen, & Hollnagel, 2009; Rollenhagen, Westerlund, Lundberg, & Hollnagel, 2010) to the exploration of socio-political influences on how investigations are conducted in practice (Nicolini, Waring, & Mengis, 2011a; Tamuz, Francheois, & Thomas, 2011).

A third body of research has attempted to evaluate the learning that has arisen from LFI. For example, Madsen, Dillon, and Tinsley (2016) statistically analysed the number of incidents experienced by 64 US airlines, concluding that there was evidence of significant learning following accidents or near-misses that had previously been associated with accidents. Furthermore, several researchers (J. E. Anderson, Kodate, Walters, & Dodds, 2013; Braut & Njå, 2013; Jacobsson, Ek, & Akselsson, 2011, 2012; Stackhouse & Stewart, 2017) examined written reports and recommendations produced following an incident using rubrics to assess the theoretical quality of learning to which the reports could lead.

1.2 The Problem
When considering the LFI process outlined by both Littlejohn et al. (2017) and Drupsteen et al. (2013), research to date has mostly investigated the phases of reporting and investigation. However, one step that remains relatively unexplored is communicating the results of incident investigations (Drupsteen & Guldenmund, 2014; Lindberg, Hansson, & Rollenhagen, 2010). Research in the wider context of workplace learning has shown that networks are vital for learning in a variety of ways (Hakkarainen, Palonen, Paavola, & Lehtinen, 2004). While the formal networks within an organisation, such as interactions between front-line workers and their supervisors, are undoubtedly important for disseminating incident alerts (Alsamadani, Hallowell, & Javernick-Will, 2012), there likely are also informal networks alongside the formal ones that play a role in LFI (Gressgård & Hansen, 2015); in other words spontaneous interactions that involve discussion of incident-information. Furthermore, the distribution of incident alerts should lead workers to consider how an incident applies to their own work (Margaryan, Littlejohn, & Lukic, 2018). How communication on incidents leads to contextualisation is also yet to be explored by research (Margaryan, Littlejohn, & Stanton, 2017).

Hence, there are several gaps that must be addressed related to networks and communication in the context of LFI. While some studies have examined databases used as tools to share incident-information between groups (J. G. Anderson, Ramanujam, Hensel, & Sirio, 2010;
Jacobsson, Sales, & Mushtaq, 2009), no study to date has examined the structure of the formal networks that enable incident-information to be distributed, or of the informal networks that support them. Likewise, while networks play an obvious function in the dissemination of incident alerts phase of the LFI process, they should play other roles, such as enabling the contextualisation of incident alerts (Margaryan et al., 2018). Hence, investigating the functions that networks play in LFI is needed. While there are many potential areas regarding communication that warrant investigation in LFI, understanding the structure and purpose of networks is an essential foundation on which to build future studies.

In addition, while understanding network functions is one of the clearest gaps that exist within the literature on LFI, networks are influenced by the culture and traditions of a workplace, and should be placed within a context (Emirbayer & Goodwin, 1994). Understanding the context of networks is vital, as the motivations, practices, culture, and history of a group will strongly influence how networks are shaped and used (Borgatti, Brass, & Labianca, 2009; Engeström, 2001). The most important aspect of the cultural considerations in a workplace is the perceived objectives of an activity, in this case the perceived objectives of LFI (Roth & Lee, 2007). It is these objectives that will drive the actions of individuals (Wilson, 2014). From the LFI literature, it is clear that the desired outcome of LFI is to reduce the number of incidents (Le Coze, 2013), and that this aim should be achieved by accomplishing the objective of learning (Braut & Njå, 2013).

Learning can be considered in a variety of ways (Paavola, Lipponen, & Hakkarainen, 2004; Sfard, 1998). In articles on LFI learning has been evaluated, but not always defined. For example, Madsen et al.'s (2016) 64 airline statistical analysis focused on what should result from learning, using a reduction in the number of incidents as a proxy for learning, but never explicitly defining what learning entailed. Other studies have had clear definitions of learning, but focused on different aspects. Vastveit, Boin, and Nja (2015), for example, considered learning to be related to knowledge embedded in daily practices and routines, while Deverell (2009) depicted learning as changes to organisational models. While learning has been acknowledged as the objective of LFI, there is an implicit and often inconsistent understanding of what learning entails in this context (Margaryan et al., 2017). How learning is perceived and conceptualised with relation to LFI is a current gap in the literature that must be addressed, not only for exploring whether LFI is successful, but also for placing networks within a context.

While the objectives of a community of workers are the driving force for their actions, therefore playing an important role in how networks are used in LFI, other cultural factors likewise influence both how objectives are achieved and how networks are formed. Some studies have provided examples of the beneficial strategies for LFI by organisations (Lukic, 2012; Vastveit
et al., 2015; Vastveit, Orszak, Njå, & Kraslawski, 2017), as well as highlighting barriers that prevent LFI from taking place effectively (Drupsteen & Hasle, 2014; Haw et al., 2014). Case studies, i.e., in-depth examinations of particular phenomena in practice (Yin, 2013), are essential resources for developing expertise, demonstrating how theoretical concepts are implemented within practical environments (Flyvbjerg, 2006). In particular, practitioners have called for more examples of how relatively theoretical notions, such as contextualising incident alerts, have been implemented in practice (Murphy, Lawrie, & Littlejohn, submitted). Moreover, while case studies have identified several barriers to learning, these investigations have tended to focus on issues that would lead to incremental improvements on the current system if addressed, such as monitoring if recommendations from incident alerts are implemented (Stackhouse & Stewart, 2017), providing better feedback to front-line workers (Lukic, 2012), or ensuring sufficient time is dedicated to LFI (Drupsteen & Hasle, 2014). No study to date has examined how well current LFI systems are able to achieve their objective of learning, as no study has yet explored what practitioners understand by learning in LFI.

1.3 Research Aims and Contributions

This research aimed to build upon the conceptualisation of LFI as a process to enable the learning of individuals, teams, organisations, and networks. Initially, this took the form of addressing a specific gap identified by two literature reviews on LFI: communication of incident-information (Drupsteen & Guldenmund, 2014; Lindberg et al., 2010). This gap was addressed by examining the functions that networks play within LFI using mixed methods social network analysis (SNA) in three case studies. However, as networks must be placed within a cultural context in order to be interpreted (Crossley et al., 2015), the environments of each case study were conceptualised using an activity theory framework. This holistic examination of LFI in each case study additionally addressed the gap of defining learning from a practitioner standpoint in LFI. Lastly, the research presented here illustrates beneficial strategies for LFI, as well as identifies underlying contradictions that would act as a barrier to achieving the objective of learning. The specific research questions addressed are:

RQ1: How are networks used in LFI? (Chapter 5)

RQ2: What do workers perceive as successful learning in the context of LFI? (Chapter 6)

RQ3a: What beneficial practices in LFI enable learning? (Chapter 7)
RQ3b: What barriers to learning exist in the LFI process? (Chapter 7)

The thesis will contribute:

- A detailed understanding of the different types of network activities that exist within LFI, including how they relate to the phases of the LFI process as outlined by Littlejohn et al. (2017) and Drupsteen et al. (2013) (Chapter 5)
- A taxonomy of what practitioners understand as successful learning (Chapter 6)
- Examples of beneficial practices in LFI (Chapter 7)
- The identification of contradictions that hinder LFI systems from fostering successful learning (Chapter 7)

Initially, the thesis will focus on the justification of the research questions, as well as detailing the theoretical framework and research design of the case studies. Chapters will then present analyses to address each research question, highlighting novel contributions to theory. The final chapter will summarise contributions to knowledge from the perspective of theory, methodology, and practice. A more detailed explanation of the structure of the thesis is provided below in Section 1.4.

1.4 Thesis Structure

Chapter 1: Introduction

This initial chapter of the thesis has discussed why LFI is an important topic for research. Furthermore, it has briefly summarised some gaps in the literature on LFI that will be addressed, and outlined what contributions this thesis provides to knowledge.

Chapter 2: Literature Review

The second chapter of this thesis presents a more detailed overview of research related to learning in the context of LFI. LFI is a form of learning that takes place in the workplace, and thus can be considered from the individual, team, organisational, or network level. The literature review chapter summarises what theories have been used to understand learning at each of these levels, and what is known in each case. Finally, gaps in research on LFI as a form of learning are highlighted and presented as research questions.
Chapter 3: Theoretical Framework
Chapter 3 presents information on the theoretical frameworks that have been used to underpin the research design employed in this thesis. SNA, activity theory, and the 3-P model of workplace learning are discussed.

Chapter 4: Methodology
This chapter begins with a discussion on the nature of LFI in relation to the research questions, and therefore the requirements of methods in this thesis. It then outlines the strengths and limitations of mixed methods designs, case studies, and the specific data collection methods used. The chapter concludes with a detailed research design, providing insight into how the aforementioned methodological considerations were transformed into research practice. Chapter 4 is intended to provide background on methodological details and justifications, as well as outline common features across different analysis chapters, such as the organisational contexts of each case study. However, for ease of reference, specific analysis techniques are described within Chapters 5 – 7, alongside reporting and discussing results.

Chapters 5: Networking in Learning from Incidents
Chapter 5 is the first of the analytical chapters of this thesis and focuses on RQ1. It presents the results of mixed methods SNA based on 162 responses to a network survey, and 45 interviews. At first, the quantitative results of a social network survey are presented and analysed at both the network- (i.e., team) and ego- (i.e., individual) level. This quantitative overview allows the reader to gain insight into the structure of the networks. The quantitative data is then complemented by qualitative analysis of interview data to examine how workers used their networks in relation to LFI. The chapter ends with a discussion on the important features of information-exchange activities in the workplace, and during what phases of the LFI process these activities occur.

Chapter 6: Perceptions of Learning
The second analysis-based chapter of this thesis, Chapter 6, presents the results of a thematic analysis of interview data. The analysis was based on the same 45 interviews used for analysis in Chapter 5. Learning was operationalised as both a process and a product using the 3-P model of workplace learning. The thematic analysis initially identified what was perceived to be either a
desirable product of learning, or what was necessary to enable a learning process. The results of the analysis are presented as a taxonomy. Furthermore, statistical analysis was then employed to determine evidence of a difference between the perceptions of the front-line and managerial workers. Finally, the chapter ends with a discussion of how the taxonomy relates to concepts of learning in LFI in the literature.

Chapter 7: Resources and Inhibitors of Learning

Chapter 7 is the final chapter to present analysis conducted in relation to the three case studies and split into two parts. Initially, the results of 165 responses to a validated survey are presented to identify strengths and weaknesses of the LFI process in each organisation. These results are followed by creating a description of the activity system for LFI in each case, drawing upon the analysis of Chapter 5 and Chapter 6, as well as extracting additional details from the data of the 45 interviews. A summary of beneficial practices is then presented, and the results of the survey contrasted with the qualitative descriptions of the activity systems.

The second half of the chapter focuses on the fundamental contradictions in the activity system that create barriers to LFI. A discursive analytical approach was used to identify tensions in the dialogue of interview participants. From these tensions, four underlying contradictions were identified. The contradictions are described in depth, and compared to the results of the validated survey and the qualitative descriptions of the LFI systems. Discussion at the end of the chapter concentrates on beneficial practices that are novel in the context of LFI, and implications of the identified barriers.

Chapter 8: Discussion and Conclusions

The final chapter of the thesis presents an overview of this research’s theoretical and methodological contributions to knowledge. Furthermore, it discusses implications for practitioners based on the results of Chapters 5 - 7. The chapter ends by discussing major limitations of the thesis and directions for future research.

1.5 Summary

This chapter highlighted why furthering knowledge of LFI as a process to enable learning is important for society. It then provided a brief overview of what is known on LFI at the time of writing and gaps in its conceptualisation. The chapter ended with an overview of the aims and
contributions of the thesis; in other words, unpacking how networks are used in LFI, what practitioners perceive to be successful learning in the context of LFI, and identifying enablers and inhibitors of learning in LFI. An overview of the thesis structure was also provided. Chapter 2 will expand upon the brief summary of literature on LFI in relation to learning in Chapter 1, providing a more in-depth justification of the research questions stated in this chapter.
2 Literature Review

The purpose of Chapter 2 is to provide a review of the field of learning from incidents (LFI). As a multidisciplinary subject, LFI has been a topic for discussion in a variety of disciplines, such as engineering, psychology, and business management (Le Coze, 2013). For this review, LFI will be discussed from the perspective of learning, ultimately providing an overview of the current state of research on LFI as a learning process and identifying gaps that need urgent attention, forming the basis of the research questions of this thesis.

2.1 Learning from Incidents

LFI can be understood as a process where an accident or near-miss is used as a stimulus for individuals, teams, networks, or organisations to learn, with the aim of preventing accidents in the future (Drupsteen & Guldenmund, 2014; Margaryan et al., 2017; Murphy, Littlejohn, & Rienties, submitted). This process involves several phases, starting with the submission of a report on an incident (Rossignol, 2015). After a report has been created, an investigation will be initiated to understand the causes of the event, leading to recommendations on potential ways to avoid a similar situation (Rollenhagen et al., 2010). The findings of the investigation will then be distilled into an incident alert, which is distributed across an organisation (Margaryan et al., 2018). After teams and individuals have received information on an incident, they need to reflect upon it, making sense of the information contained within the alert in their own context (Littlejohn et al., 2017; Lukic, 2012). Finally, reflection should lead to changes being implemented, which will then be evaluated for their effectiveness at preventing an incident (Drupsteen et al., 2013).

2.2 Definition of Incidents

Before exploring literature on how incidents prompt learning through LFI, it is first necessary to define an incident. While there is a large amount of literature on incidents in the field of safety science, as well as related concepts such as errors and disasters, only the most relevant aspects of incidents to learning are presented here. Incidents, with respect to LFI, are usually defined as both accidents and near-misses, i.e., events that could potentially have led to undesirable results (Drupsteen & Guldenmund, 2014). An incident does not necessarily require an individual to have

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1 Sections of this chapter are adapted from the following submitted journal article: Murphy, V. L., Littlejohn, A., & Rienties, B. (submitted). A scoping review: Educational theories underpinning learning from incidents in the aviation, energy and healthcare industries. Safety Science.
made a mistake for an unwanted event to occur. For example, perhaps a rule that an individual has applied correctly according to procedures was flawed (Reason, 1995). Equally, as workers are embedded in a complex socio-techno environment, incidents can occur due to perceived pressures or miscommunications (Ferjencik, 2011).

While accidents and near-misses are almost universally understood to be events that can stimulate learning through the LFI process, in practice it is less clearly defined what counts as an incident. Factors such as perceived learning value or the actual outcome influence whether an event is understood as an incident (Gilbey et al., 2016; Rossignol, 2015; Sanne, 2008). While academically there is a consensus on a safety incident consisting of an adverse event that could lead to injury (Hollnagel, 2014), there remain practical difficulties for workers to assess what this means in reality (Stemn, Bofinger, Cliff, & Hassall, 2018).

An additional aspect of the discussion on incidents relates to whether learning can also occur from studying non-adverse events. For example, Sanne (2012) related a situation where a nuclear power plant focused on the negative events that occurred when an accident was narrowly avoided, but neglected to learn from the good examples set by operators. Walker (2017) likewise discusses how the black box in a plane has effectively become redundant in aviation, as there are now so few incidents. He argued that the data collected by the black box could be used to learn about situations where incidents did not occur. M. A. Sujan, Huang, and Braithwaite (2016) similarly observed that incidents are relatively rare, and there are far more opportunities for learning if every-day events are deliberated.

As shall be discussed below, the LFI process closely resembles a cycle of experiential learning, defined as reflection on an event which in turn learns to learning (Kolb, 1984). As such the definition of an incident considered in this thesis is based upon the events that stimulate learning as described by the educational philosopher John Dewey, one of the thought leaders on experiential learning (Biesta & Burbules, 2003). An incident is therefore defined as an unexpected encounter that challenges the previously held beliefs in a person’s worldview (Dewey, 1910).

It should be noted that as the definition of an incident is relatively broad in this thesis, several research areas can be viewed as related to LFI, but with a more specific definition of an incident. For example, learning from accidents relates to situations that had negative consequences, and would exclude near-misses (Hovden, Størseth, & Tinmannsvik, 2011). Similarly learning from errors is a research area where an incident has occurred due to a mistake, for example in how a rule was applied or in the creation of the rule (Reason, 2000). However, in the
definition of this thesis an incident is not necessarily associated with a mistake, as much as an unexpected situation.

2.3 Learning from Incidents at Different Levels

After considering the definition of an incident, the second important feature to consider in LFI is learning. As outlined by multiple summaries of learning in professional contexts (e.g., Edmondson & Lei, 2014; Hakkarainen et al., 2004; Tynjälä, 2008), learning in workplaces occurs at four levels: organisations, networks, groups, and individuals. In this thesis learning at these different levels is defined as follows:

- Organisational learning can be defined in a variety of ways (Wang & Ahmed, 2003), but in this thesis will be considered as updates to organisational processes or systems.
- Learning at the network level is defined as knowledge-exchange between different entities (Hakkarainen et al, 2004). These entities may be organisations, groups within the same organisations, groups in different organisations, or individuals.
- Learning at the group level is considered as knowledge embedded within a group’s practices and tools (Wenger, 1998).
- Finally, learning at the individual level is considered to be a change in either an individual’s behaviours or an update in their cognitive model of the world that could impact their behaviour (Driscoll, 2000).

From the LFI process outlined above in Section 2.1, the notions of learning in networks and groups can be understood as integral parts of LFI: dissemination of incident alerts between and within groups are key steps in the LFI process (Littlejohn et al., 2017). Nonetheless, communication has been highlighted in two literature reviews on LFI as an area that needs to be further investigated (Drupsteen & Guldenmund, 2014; Lindberg et al., 2010).

Examination of the LFI process model suggested by Littlejohn and colleagues (Littlejohn et al., 2017; Margaryan et al., 2018), shown in Figure 1, suggests that the LFI process must also include the learning of both individuals and organisations. The model shows that the desired outcome of the LFI process is either a change in behaviour of individuals, in line with definitions of individual learning (Driscoll, 2000), or updated processes, a form of organisational learning (Argyris & Schön, 1996).

The following sections will summarise what is currently known about learning in the context of LFI, first by considering learning at the network and group level stimulated by the
exchange of incident-information, and then, secondly, by examining how incident-information transforms both individuals and organisations. At all levels multiple learning theories have been used to conceptualise learning. The following presents the different learning theories drawn upon at each level in LFI as identified in Murphy, Littlejohn, et al.’s (submitted) systematic literature review. What is known at each level of learning is detailed below.

![LFIQ process model](image.png)

**Figure 1 LFIQ process model (Littlejohn et al., 2017; Margaryan et al., 2018)**

### 2.3.1 Learning from Incidents as a Form of Networked Learning

The exchange of incident-information is an important step within the LFI process (Drupsteen et al., 2013). In its simplest form, it can allow workers to possess a better understanding of risks. From the perspective of the LFI process, receiving information is a necessary step for workers not involved in an incident to connect insights from an incident investigation to their own work (Nonaka & Takeuchi, 1995). Furthermore, exchange of incident-information is not limited to communication between groups within an organisation, but can be expanded to diffusion across multiple organisations and sectors.

For example, Jacobsson et al. (2010, 2009) analysed more than 500 reports in the Major Accident Reporting System database to explore the quality of incident-information exchanged between organisations. They established that the database entries contained relatively superficial recommendations and insights. J. G. Anderson et al. (2009) similarly looked at a database for sharing information among hospitals in the US. They found that the number of reports submitted
significantly increased after the initial introduction of the database, but there was no evidence that the quality of the reports increased. If databases are to enable the learning of other teams, organisations, or potentially even industries, the information within submissions must contain sufficient detail on the context of the incident. This need was explicit in the criteria suggested by Braut and Njå (2013) for assessing organisational incident reports. If database entries fail to contain adequate details for others to find connections to their own work tasks, learning is unlikely to occur (Snowden, 2002).

Knowledge-exchange is not only spurred by explicitly trading information, it can also occur tacitly by working on every-day tasks with others (Billett, 2014; Eraut, 2000; Nonaka & Takeuchi, 1995). Gressgård and Hansen (2015) theorised that as contractors work with several teams within an organisation, they would be in an ideal position to spread knowledge. Their analysis of 2,653 questionnaires, answered by employees of a Norwegian oil organisation and eight of its contractor organisations, found that contractor relationships were indeed a predictor of perceptions of knowledge-exchange and LFI effectiveness. By working closely with a range of organisations and their employees, contractors are the recipients of knowledge and best practices developed following incidents. These best practices are then subsequently spread as the contractors work alongside new groups.

In general, there have been few studies that have explored the mechanisms of how networks enable learning in the context of LFI compared to the broader field of workplace learning (Murphy, Littlejohn, et al., submitted). For example, research has investigated the role that connections between organisations played in creativity via creating pathways for workers to bring fresh ideas and perspectives to their organisations (Burt, 2004; Daly & Finnigan, 2011). Other case studies have unpacked the way that networks enable professional teams to fluidly come together to solve problems (Engeström, 2008b). When discussing knowledge-exchange in workplaces a distinction has been made between easily codified knowledge, i.e., relatively simple concepts that do not require a common underlying understanding to communicate, and complex ideas that are often tacit (Hakkarainen et al., 2004). For example, Nonaka and Takeuchi (1995) examined several cases studies exploring how innovations occurred in a wide variety of organisations. Initially knowledge was exchanged tacitly by working closely with others on everyday tasks. Learning in this manner will be discussed in detail below, but new knowledge was theorised to be created through making tacit knowledge explicit in documents and instructions that could be distributed to a wide audience (Paavola et al., 2004). The research to date on networked learning in LFI suggests that both complex tacit knowledge and codified explicit knowledge are relevant. In the studies of databases by Jacobsson et al. (2009, 2010) and J. G.
the results of incident investigations were distilled down into reports that both sets of researchers found overly simplified. Additionally, Gressgård and Hansen's (2015) study was based on theories of tacit knowledge transfer. Networks clearly play multiple functions in enabling learning in the context of LFI. Nonetheless, a gap exists within the literature in investigating what functions networks have in LFI and how they enable learning. The first research question addressed in the thesis will therefore be:

**RQ1:** How are networks used in LFI?

### 2.3.2 Learning from Incidents as a Form of Group Learning

From the group perspective of LFI, an emphasis has been placed on learning through participation (Sfard, 1998). As outlined by Paavola et al. (2004) learning by participation involves learning while accomplishing tasks with others. The theories that have been drawn upon in LFI to make sense of learning at the group level are situated learning (e.g., Sanne, 2012), informal learning (e.g., Bauer & Mulder, 2007), and sensemaking (Catino & Patriotta, 2013).

#### Situated and informal learning

Learning theories drawn upon at the group level of LFI largely pertain to learning through participation in a community, often termed ‘situated learning’ (e.g., Sanne, 2012; Silva et al., 2017). This view of learning is usually described as ‘informal’, and is often linked to developments while performing an employee’s job (Lukic, Littlejohn, & Margaryan, 2012). Informal learning can be considered as any learning that takes place outside of a formal setting (Manuti, Pastore, Scardigno, Giancaspro, & Morciano, 2015). While occurring outside a formal structure, informal learning can still be deliberative, such as setting time aside to read professional magazines (Bauer & Mulder, 2007). Eraut (2000, 2004) proposed a set of dimensions that together constitute informal learning, shown in Table 1.

In the case of LFI, situated learning has been used to describe a form of informal learning where understanding is accumulated, often unconsciously, by participation in a community working together (Silva et al., 2017). Knowledge is not only possessed by individuals, but also historically accumulated within the tools, procedures, and routines that are used as part of daily work (Yoon, Ham, & Yoon, 2016). Context and the objectives of employees are therefore of utmost importance for LFI; events and reports will be interpreted based on what is known and
accepted by the group (Gherardi, Nicolini, & Odella, 1998). Additionally, a team’s priorities will affect the actions taken following an incident (Wilson, 2014).

Braut and Njå (2013) used these concepts as a basis to evaluate the potential learning gained from an incident by considering the context, content, and commitment evidenced in internal and external reports. Their conclusions were that internal reports could be useful tools for reflection, but often did not include enough details on context. External reports, on the other hand, focused on the organisational context and the factors that had contributed to incidents. From the perspective of situated learning it is crucial that incident reports and alerts, the tools used to inform most of the workforce about an incident and the findings of its associated investigation, include details on the context. Without these details workers will be unable to relate the incident-information to their daily work, the most frequent way in which learning occurs in workplaces (Billett, 2014; Tynjälä, 2008).

<table>
<thead>
<tr>
<th>Time of focus</th>
<th>Implicit learning</th>
<th>Reactive learning</th>
<th>Deliberative learning</th>
</tr>
</thead>
<tbody>
<tr>
<td>Past episode(s)</td>
<td>Implicit linkage of past memories with current experience</td>
<td>Brief near-spontaneous reflection on past episodes, events, incidents, experiences</td>
<td>Discussion and review of past actions, communications, events, experiences</td>
</tr>
<tr>
<td>Current experience</td>
<td>A selection from experience enters episodic memory</td>
<td>Noting facts, ideas, opinions, impressions; asking questions; observing effects of actions</td>
<td>Engagement in decision making, problem solving, planned informal learning</td>
</tr>
<tr>
<td>Future behaviour</td>
<td>Unconscious expectations</td>
<td>Recognition of possible future learning opportunities</td>
<td>Planning learning opportunities; rehearsing for future events</td>
</tr>
</tbody>
</table>

Table 1 Dimensions of informal learning (Eraut, 2004, p.250)

Sensemaking
Sensemaking can be viewed as a central component of situated learning, as it is defined as a continual retrospective process of explicating why events have happened (Weick, Sutcliffe, &
Obstfeld, 2005). In LFI sensemaking of incidents, and predicting outcomes of future actions, are heavily influenced by a team’s safety culture. Safety culture could be considered at the level of the whole organisation, but researchers have proposed that each team has their own culture related to safety (Gherardi et al., 1998). This view was supported in LFI research by multiple studies measuring safety culture (e.g., Abdi, Delgoshaei, Ravaghi, Abbasi, & Heyrani, 2015; Armitage, Newell, & Wright, 2010).

Catino and Patriotta (2013) looked at specific examples of how safety culture can influence LFI through sensemaking. They observed in their study of an Italian airbase, that the team culture had a strong influence on how incidents were perceived and subsequently learned from. ‘Murphy’s Law’, i.e., the idea that anything that can go wrong will go wrong, was often spoken about by the pilots. This perspective caused them to see accidents as a series of events that went wrong, rather than blaming an individual.

Other studies have also attempted to understand the link between culture and learning in LFI. Several articles have explored this relationship through validated questionnaires, by measuring perceptions of safety culture and learning outcomes from the LFI process (Chiang, Hsiao, Lin, & Lee, 2011; Verbeek-Van Noord, Wagner, Van Dyck, Twisk, & De Bruijne, 2014). These studies have suggested that several factors of safety culture can impact the ability of employees to learn as a result of an incident, such as teamwork, open communication, and management support.

Another element of safety culture that affects LFI through impacting sensemaking is psychological safety. Psychological safety is defined as a shared belief between members of a group that they can take interpersonal risks, such as admitting to a mistake, without fear of negative consequences (Edmondson & Lei, 2014). In a pioneering paper Edmondson (1999) found that there was a statistically significant relationship between team psychological safety and team performance, mediated by team learning behaviours. In later work investigating LFI it was revealed that the relationship between the number of incidents reported and team dynamics were complex, as teams with better team work actually reported more incidents (Edmondson, 2004). It was theorised, and empirically tested, that this was due to teams with high psychological safety feeling more secure that negative consequences would not result from reporting an incident (Leroy et al., 2012). Sensemaking, influenced by safety culture, not only effects how workers understand incident-information that they receive, but also impacts whether they will engage with LFI at all (Lukic, Margaryan, & Littlejohn, 2013).
2.3.3 Learning from Incidents as a Form of Individual Learning

Individual learning has been considered in a variety of studies. A large body of work has investigated how an individual learns following involvement in an incident, drawing from the theory of experiential learning (e.g., Bauer & Mulder, 2011). Other studies have focused on whether an individual chooses to involve themselves in the LFI process at all, focusing on elements of agency and identity (e.g., Lukic et al., 2013).

Experiential learning

One theory that has frequently been used to explain how individuals learn following incidents is experiential learning. Experiential learning involves a cycle of experiencing an event, reflecting upon the event, developing new strategies or modifying assumptions, and then testing the updated understanding (Biesta & Burbules, 2003; Kolb, 1984). A similar cyclic process has been described in several articles on LFI, but not necessarily called ‘experiential learning’ (e.g., Chang and Mark, 2011). For example, in Koehn, Ebright, and Draucker’s (2016) grounded theory-based investigation of nurses’ experiences of learning from errors, a version of an experiential learning cycle was deduced. It should be noted that a strong connection exists between sensemaking and individual reflection as part of experiential learning. Both sensemaking and reflection involve trying to make sense of incidents in the past. In this thesis, sensemaking is defined as a continuous process of updating views on how the world functions, while reflection refers to the contemplation of an individual event (Murphy, Littlejohn, et al., submitted).

Bauer and Mulder (2007), through ten interviews with experienced nurses, focused on different endeavours that could take place during the experiential learning cycle following an error. Their results found that several different activities can form part of the continuous learning process, e.g., learning through discussions with colleagues, reflection as an individual, or attending formal training. It should be noted that social activities enabled reflection, but were seen as a way to aid individuals in reflecting on events, rather than as a form of team learning (Bauer & Mulder, 2011; Leicher et al., 2013).

In a similar manner, group meetings have been considered as an opportunity to enable individuals to reflect with others in the context of LFI. Reiter-Palmon, Kennel, Allen, Jones, and Skinner (2014) monitored the use of meetings between practitioners immediately following an incident. Through the analysis of 226 reports, the researchers observed that, over time, the number of incidents fell as more meetings were held. On the other hand, J. E. Anderson and Kodate (2015) undertook an ethnographic study to investigate the effectiveness of incident
review meetings at two UK hospitals. Their results showed that many factors determined the effectiveness of meetings, such as support from the wider organisation. The skill of the facilitator of the meeting was also mentioned as having an impact on the meeting’s results. Nicolini et al. (2011a) noted similar inconsistencies in the effectiveness of meetings in a hospital environment. Meetings can be highly effective at providing opportunities to reflect on incidents, and enabling discussion on what changes could prevent similar events happening again. However, there are often inconsistencies in how meetings are carried out, which impacts their effectiveness.

A consistent LFI process within an organisation helps to ensure that individuals are guided through high-quality learning activities, prompting reflection and individual growth (Rossignol & Hommels, 2017). Left unguided, an employee may take the initiative to use accidents as an input to the experiential learning cycle, such as reading incident reports (Vastveit et al., 2015), or taking part in well-structured group meetings (Reiter-Palmon et al., 2015). However, the quality of learning will vary from employee to employee.

Identity and agency

Identity and agency have formed the basis of a wide range of studies in workplace learning. Identity refers to an individual’s views on their inner values, beliefs, and ethical standards (Eteläpelto, Vähäsantanen, Hökkä, & Paloniemi, 2014). This is a concept closely linked to professional agency, which can be defined as the practice of an individual making choices, or acting in a way to influence their professional situation (Eteläpelto, Vähäsantanen, Hökkä, & Paloniemi, 2013). Agency takes into consideration identity related factors, such as self-efficacy, but is also driven by external circumstances, such as what an individual believes is expected of them (Bandura, 2001). An important aspect of both identity and agency is their temporal nature, as past experiences influence current beliefs and understandings, as well as expected futures (Biesta & Tedder, 2007). The interplay between identity, environmental influences, expectations, and agentic decisions all affect the eventual concrete outcomes observed in a workplace (Kira & Balkin, 2014).

Lukic et al. (2013, 2012) are, to my knowledge, the only researchers to explicitly include agency in their theoretical LFI framework. However, many others have investigated factors that affected motivation and involvement in LFI, which can be interpreted through an agentic lens. Lukic et al. (2013) conducted 37 semi-structured interviews across two organisations in the energy sector, to explore individual and organisational factors influencing individuals’ willingness to take part in the LFI process. Five individual factors were found to influence how people engaged with
LFI: safety values, experience, confidence, proactivity, and individual gains. These individual factors were complemented by three organisational factors that affected the agency of an individual: pathways for participation, encouraging input, and feedback. While Lukic et al. (2013) presented factors as separate considerations, they noted connections, such as personal experience affecting confidence and proactivity.

Individual agency has been examined in detail from the perspective of barriers to reporting. For example, in the healthcare sector several qualitative studies came to the conclusion that prior experience influences the perception of an incident, and therefore how likely it is to be reported (Espin, Wickson-Griffiths, Wilson, & Lingard, 2010; Haw et al., 2014; T. A. Hewitt & Chreim, 2015). In addition, fear of consequences for oneself or another, as well as workload, have been identified as factors that can prevent someone from reporting an incident (Alqubaisi, Tonna, Strath, & Stewart, 2016; Chiang et al., 2011; Chiang, Lin, Hsu, & Ma, 2010; Dillman et al., 2011; Moumtzoglou, 2010; Sanghera, Franklin, & Dhillon, 2007).

Gartmeier et al.’s (2017) study quantitatively explored the relative importance of different influences on individual agency. Their survey of 73 nurses suggested that the benefits of learning were perceived to outweigh negatives, such as effort and damage to personal image. Bauer and colleagues similarly created and tested a model exploring factors that affected a nurse’s likelihood to engage in incident-related social learning activities (Bauer & Mulder, 2011; Leicher et al., 2013). Their results suggested that the perception of an incident as a valuable learning experience, and a person’s tendency to cover up errors, were both significant predictors of engagement. These factors were additionally supported in J.E. Anderson and Kodate’s (2015) qualitative investigation of two hospital’s LFI systems, where staff understood a wide variety of possible benefits, but perceived challenges related to time, coordination, skills, and blame assignment.

Other studies have built upon the organisational factors affecting engagement suggested by Lukic et al. (2013). J. E. Anderson et al. (2013) found that feedback impacted engagement, as those not involved directly with the investigation process lacked knowledge of what was happening, or how the LFI system worked. Transparency of the LFI system, similarly, was found to have a statistically significant influence on whether an incident was reported in Pfeiffer, Briner, Wehner, and Manser’s (2013) survey of 818 Swiss nurses.

Employees appear to understand that LFI can be a beneficial learning process, leading to improvements in procedures and systems, and reducing the likelihood that individuals will make mistakes (J. E. Anderson et al., 2013; T. Hewitt et al., 2016). Nonetheless, there exists a range of potential barriers that affect an individual’s actual engagement. Some of these are organisation
would have little influence over, such as the individual’s prior experiences. However, most factors could be affected by an organisation, such as ensuring a transparent system where benefits are clear, and employees can feel secure when discussing incidents openly.

**Expectations of LFI**

Whether viewed through the lens of culturally-influenced sensemaking or identity-shaped agency, how effective LFI is as a method of learning is affected by the subjective interpretation of individuals. Research to date has shown that workers can appreciate LFI as beneficial to individuals, teams, and organisations (J. E. Anderson et al., 2013; Gartmeier et al., 2017; T. Hewitt et al., 2016). However, given that perceived purpose and expected outcomes are the driving force of how people will act in the context of LFI (Bandura, 2001; Engeström, 2000b), no studies to date have investigated what workers understand as its goals, i.e., what is understood as successful learning. Sensemaking, reflection, and agency have all been investigated and found to be noteworthy in LFI (Bauer & Mulder, 2007; Catino & Patriotta, 2013; Lukic et al., 2013). However, the more basic question of what people perceive as the purpose of LFI is yet to be addressed. This is particularly important as learning in general has several interpretations in the workforce, such as improvements to daily tasks (Billett, 2002) or an improved ability to adapt to unexpected situations (Carbonell, Stalmeijer, Könings, Segers, & van Merriënboer, 2014). To address this need, the second research question of this thesis is:

**RQ2:** What do workers perceive as successful learning in the context of LFI?

### 2.3.4 Learning from Incidents as a Form of Organisational Learning

This final section details how LFI has been conceptualised as a form of organisational learning. More studies have focused on the organisational level of learning than the individual, group, or network level (Murphy, Littlejohn, et al., submitted). The theories of Argyris and Schön (1996) have been influential at this level. In particular, studies have built a theoretical foundation on the concepts of espoused theory versus theory-in-use (e.g., Drupsteen et al., 2013) and single- and double-loop learning (e.g., Deverell, 2009).
Espoused theory versus theory-in-use

A key notion in organisational learning is ‘espoused theory versus theory-in-use’ (Argyris & Schön, 1996). This theory can be understood as the difference between how a process should be carried out and used according to official documentation, i.e., the espoused theory, and how it is used in practice, i.e., the theory-in-use. Rossignol (2015) gave one example of this in the context of LFI through investigation of socially-accepted LFI practices at a Belgian nuclear research centre. While the official rules stated all incidents should be reported into the formal incident reporting system, the accepted practice was to consider whether others could learn from the incident before reporting it. Workers usually arrived at a decision through discussion with colleagues. Similar situations were observed by M. Sujan (2015) and Espin et al. (2010) in hospitals, where unofficial discussions allowed staff to learn without the barriers that could prevent reporting. Nonetheless, informal discussions had the disadvantage that insights were kept to a local level, rather than shared throughout the organisation.

This socially-accepted use of the LFI system was also observed in two ethnographic studies on hospitals (Nicolini et al., 2011a; Tamuz et al., 2011). Both studies provided examples of an accident being used as a catalyst to enact improvements, which had already been desired by a group without the power to authorise change. While formal systems may be created with specific purposes in mind, the roles they play are varied and socially negotiated (Vastveit et al., 2015; Vastveit & Nja, 2014). The LFI process is a good example of a system that on paper has straightforward steps, but in reality, is used in multiple socially-accepted ways.

Single-loop, double-loop, and deutero-learning

Argyris and Schön’s (1996) concept of ‘single- and double-loop learning’ has been explicitly drawn upon by several articles on LFI. Single-loop learning refers to incremental improvements to a system. Double-loop learning can be conceptualised as a deeper type of learning than single-loop learning. It requires the assessment of the system itself in relation to its goals and assumptions, and may require complete redesigns of procedures and tools. In theory, both single- and double-loop learning should be a natural part of the LFI process, as incident investigations can lead to both types of learning. For example, imagine an incident where a worker became unconscious due working in a confined space with a gas leak. Single-loop learning could be to equip workers with gas masks to provide them with protection from gas leaks. However, in this hypothetical organisation it may be that there were checks in place that should have identified the gas leak, which were not carried out due to pressure to complete tasks quickly. Double-loop learning in this case might involve empowering workers to push back against their supervisors who were
themselves under pressure. In that case, the organisational incentives and deterrents for both the worker and manager would need to be considered to address the underlying cause of the incident. Compared to single-loop learning, double-loop learning is often more difficult to achieve, but targets problems, such as cultural expectations, that would be relevant to a wide range of incidents.

Single- and double-loop learning have often been referred to in articles that present frameworks to describe LFI. For example, Lukic, Margaryan, and Littlejohn (2010) and Deverell (2009) both presented the theory of single- and double-loop learning as a factor for consideration in their frameworks. In other words, the researchers proposed that whether fundamental issues are being identified in LFI should be considered when evaluating an LFI system, or whether only relatively superficial problems are being resolved. Single- and double-loop learning has also been operationalised by researchers to enable them to assess the quality of recommendations produced by incident investigations (Jacobsson et al., 2011; Silva et al., 2017). This assessment of how effective LFI is as a form of learning can be classified as deutero-learning. Deutero-learning was described by Argyris, (2003) in the following way:

*We understood deutero-learning to mean second-order learning, reflecting on the first-order actions. Deutero-learning can occur by going meta on single or double-loop learning.*

(p. 1179)

In this definition single-loop and double-loop learning are considered the first-order actions. In other words, deutero-learning represents a strategy where the learning process itself is reflected upon. This reflection can either focus on a learning process that results in incremental and relatively superficial improvements, i.e., a single-loop learning process, or a process that results in transformational improvements by tackling fundamental problems, i.e., a double-loop learning process. In LFI deutero-learning therefore represents reflection upon the LFI process, assessing how well it is able to achieve its desired outcome of reducing the number of incidents. As with single- and double-loop learning the depth of consideration can vary in deutero-learning. For example, single-loop deutero-learning in LFI would involve identifying an improvement that would slightly improve the LFI process, such as incident alerts not providing enough information on the context of an incident for others to learn (Braut & Njå, 2013). There are few examples of double-loop deutero-learning in the LFI literature. One notable example is Lundberg, Rollenhagen, and Hollnagel’s (2010) article on the recommendations of incident investigations. The article
highlighted that the recommendations of incident investigations were influenced by several factors, such as the technical knowledge of the incident investigators, the data available during the investigation, or what investigators felt could realistically be fixed.

In addition to those specifically mentioning single- and double-loop learning, numerous studies have attempted to describe and evaluate how LFI supports learning, i.e., conducting deutero-learning on LFI as a learning process. Drupsteen et al. (2013) and Littlejohn et al. (2017) both suggested a model to describe the LFI process. By combining their suggestions, the LFI process can be considered to consist of the phases outlined in Section 2.1: reporting, investigating, developing incident alerts, disseminating, contextualising, implementing actions, and evaluating changes. This set of phases is effectively an organisational-level version of the experiential learning cycle proposed by Kolb (1984), with additional phases for disseminating information to a wider audience, who will then reflect on how the information relates to their own context. Both Drupsteen et al. (2013) and Littlejohn et al. (2017) suggested that assessing each phase in their proposed process model could be used as a way to evaluate learning. It should be noted that the questionnaire created by Littlejohn et al. (2017) is based not just on the phases of the model, but also on overarching factors, such as who is involved in learning, and whether the complexity of the incident impacts the process (Lukic et al., 2012). While the phases of the LFI process are important, it is also necessary to consider the contextual aspects within each phase (Braut & Njå, 2013). In contrast to using a questionnaire, Drupsteen et al. (2013) suggested using the concept of espoused theory versus theory-in-use to evaluate how well documented each step of the LFI process was, and how well the implementation of that step in reality matched the documentation.

An alternate approach to assess the quality of the LFI process has been to focus on the outputs and outcomes. Madsen et al. (2015) created a statistical model based on 2,955 reports of 64 US airlines to evaluate if learning was happening after incidents occurred. They found significant evidence of reduced incident numbers following accidents or near-misses that had previously been associated with accidents. Conversely, Jacobsson et al. (2012, 2011) and Stackhouse and Stewart (2016) both assessed the recommendations produced by accident investigations, taking into consideration factors such as the depth of learning (i.e., single- or double-loop), the relevance across the organisation, and whether the recommendations were actually implemented.

The final way that researchers have attempted to evaluate LFI as a learning process is through the identification of barriers. Drupsteen and Hasle (2014) held focus groups with several organisations to identify what they felt were the biggest obstacles to effective LFI. Each
organisation faced its own specific issues, but some difficulties were raised frequently, such as restricted time and difficulties planning. Restrictions to learning have also been investigated by Lundberg et al., (2009), finding that the investigation processes designed to guide learning were based on many assumptions. An example of how these assumptions can limit learning was demonstrated by Sanne (2012), who found that the positive examples of operators in a Scandinavian nuclear plant, who helped to prevent an accident, were not considered as opportunities to learn. Table 2 presents a summary of the different barriers to learning that have been identified in LFI literature.

Table 2 Summary of barriers to LFI in literature to date

<table>
<thead>
<tr>
<th>Barrier</th>
<th>Description</th>
<th>Articles</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lack of agency</td>
<td>Employees do not have the ability to influence the LFI process, and received no feedback when they did offer thoughts</td>
<td>Drupsteen &amp; Hasle, 2014; Lukic, 2012; Lukic et al., 2013</td>
</tr>
<tr>
<td>Cultural issues</td>
<td>The culture of a workplace discourages reporting incidents due to a fear of repercussions, and additionally negatively influences incident follow-up</td>
<td>Bauer &amp; Mulder, 2011; Drupsteen &amp; Hasle, 2014; Lukic, 2012; Lundberg, 2010; Rollenhagen, &amp; Hollnagel, 2010; Stemn et al., 2018</td>
</tr>
<tr>
<td>Relevance of incident</td>
<td>Incident alerts are sometimes on irrelevant subjects or seen as too unique to learn from</td>
<td>Drupsteen &amp; Hasle, 2014; Lukic, 2012</td>
</tr>
<tr>
<td>Incidents over simplified</td>
<td>Incident follow-ups do not contain enough information on context, focusing only on technical details rather than containing enough details for organisation-wide learning</td>
<td>Braut &amp; Njå, 2013; Drupsteen &amp; Hasle, 2014; Jacobsson et al., 2012; Lukic, 2012; Stemn et al., 2018</td>
</tr>
<tr>
<td>Limited sharing</td>
<td>Spontaneous opportunities to share knowledge are not supported, and positive examples are not learnt from</td>
<td>Lukic, 2012; Sanne, 2012</td>
</tr>
</tbody>
</table>
Incomplete implementation of LFI process

The LFI process is not finished in its entirety, for example, by not implementing recommended actions.

Drupsteen et al., 2013; Drupsteen & Hasle, 2014; Stackhouse & Stewart, 2017; Stemn et al., 2018

Limited time

Lack of time to either reflect on incidents, submit reports, or implement actions.

Drupsteen & Hasle, 2014; Lukic, 2012; Nicolini et al., 2011b

Except for ‘cultural issues’, all the barriers highlighted in Table 2 could be addressed by incrementally improving the current process. For example, creation of incident alerts could be improved by providing rubrics, such as those created by Jacobsson et al., (2011, 2012) or Braut and Njå (2013). The studies can therefore be considered to primarily identify issues which, if resolved, would be classified as single-loop deuterol-learning of LFI. For double-loop deuterol-learning of LFI to occur, it would be necessary to identify the assumptions on which the LFI process is based. Margaryan et al. (2017) proposed that LFI needs to be further defined, with identification of the criteria for effective and lasting LFI, and with detailed understanding of the desired end-states. Without a clearly defined desired end-state, it will be impossible for organisations to deeply assess if the LFI process is a system capable of meeting its goals. Moreover, with a few notable exceptions (e.g., Drupsteen et al., 2013), the majority of studies on LFI have employed single methods of data collection and analysis in their research design. Fundamental issues and contradictions within an organisational system are often difficult to detect as they cannot be directly observed (Engeström, 2014). There is an opportunity to use a mixed methods research design to examine LFI from multiple perspectives, helping to uncover barriers that would be undetectable using a single method (Teddlie & Tashakkori, 2009).

Furthermore, in a parallel to the topic itself, there is a need for academic investigation focusing on beneficial organisational practices in LFI, as opposed to examining only negative events or opinions (Walker, 2017). There are some notable exceptions which have provided valuable case studies that other organisations could learn from (e.g., Reiter-Palmon et al., 2015; Vastveit et al., 2015, 2017). However, as both safety and learning are contextually dependent (Perin, 1995), a greater collection of case studies demonstrating beneficial practices would be of use to create better understanding of how the principles of LFI are applied in practice (Flyvbjerg, 2006).
To address the need for case-studies of beneficial practice and analysis of barriers that could lead to double-loop deutero-learning, the following research questions will be addressed in this thesis:

**RQ3a:** What beneficial practices in LFI enable learning?

**RQ3b:** What barriers to learning exist in the LFI process?

### 2.4 Summary of Chapter

The consideration of LFI by multiple disciplines has had both positive and negative effects. On the one hand, insights have emerged as aspects of the LFI process have been considered from multiple perspectives. Conversely, as highlighted by the plethora of learning theories discussed in this chapter to conceptualise LFI, the investigation of LFI by engineering, psychology, business, and so on has left a fragmented image of the theoretical underpinning of LFI as a learning process (Margaryan et al., 2017). Communication and the exchange of information across networks is definitely a vital part of LFI, yet has often been neglected by research thus far (Drupsteen & Guldenmund, 2014; Lindberg et al., 2010). Moreover, multiple papers on LFI have highlighted that learning occurs through participation in work practices in groups, but the functions of networks from this perspective is also poorly understood (Murphy, Littlejohn, Rienties, King, & Bryden, 2018b).

When considering the desired results of LFI, there is also room for further clarification. Various constructs, such as sensemaking and agency, have been invoked as theoretical bases in the literature and proven to be useful lenses through which to view LFI (J. E. Anderson & Kodate, 2015; Lukic et al., 2013). However, besides acknowledgement of LFI having benefits for practitioners, teams, and organisations, a fundamental question that these theories build on remains unknown: what do workers think LFI is trying to achieve? In other words, what do they believe is successful learning?

Finally, much research into LFI has focused on defining a process by which LFI induces learning, and then evaluating its effectiveness. Despite the identification of many barriers, no research has as yet identified issues that would prevent learning, based on the assumptions of how LFI is able to achieve its goals (Margaryan et al., 2017). Likewise, the field would benefit from more studies identifying beneficial practices that could act as guides for organisations.
2.5 Research Questions

RQ1: How are networks used in LFI? (Chapter 5)

RQ2: What do workers perceive as successful learning in the context of LFI? (Chapter 6)

RQ3a: What beneficial practices in LFI enable learning? (Chapter 7)

RQ3b: What barriers to learning exist in the LFI process? (Chapter 7)

2.6 Summary

This chapter presented an overview of how LFI has been conceptualised with regards to learning. It highlighted four gaps in the literature that will be addressed in the following chapters. As LFI is a disjointed area of learning, having been viewed through multiple theoretical lenses, Chapter 3 will present the theoretical framework of this thesis in order to ensure clarity with regards to the theories and assumptions on which this thesis is built. Chapter 4 will then build on this theoretical framework to detail a complementary research design.
3 Theoretical Framework

Chapter 2 identified gaps in the LFI literature in order to craft the research questions in this thesis. Chapter 3 describes the theoretical frameworks that were used to make methodological decisions and interpret the results of analysis.

The research questions identified in Chapter 2 were:

RQ1: How are networks used in LFI?

RQ2: What do workers perceive as successful learning in the context of LFI?

RQ3a: What beneficial practices in LFI enable learning?

RQ3b: What barriers to learning exist in the LFI process?

3.1 Selection of a Framework for RQ1

As indicated in Section 2.3.1, there is still much that needs to be unpacked on how incident-information is shared and communicated through networks (Drupsteen & Guldenmund, 2014). Nevertheless, there have been some studies in the context of LFI that have looked at this issue (J. G. Anderson et al., 2010; Gressgård & Hansen, 2015; Jacobsson et al., 2012). The majority of studies investigating communication have analysed databases that facilitate inter-organisational distribution of incident-information, usually focusing on recommendations from investigations. Jacobsson, Sales, and Mushtaq (2009, 2010), for example, examined the Major Accident Reporting System database. Their studies coded the quality of information and recommendations that each entry contained, reasoning that, without quality records, organisations not involved in the initial incident would be unable to learn. J. G. Anderson et al., (2010) employed a similar approach when examining an inter-hospital database of incident-information. This type of method gives good insight into whether information contained within a database could be used for learning. However, it may fail to capture the informal networks through which knowledge and expertise are often transmitted (Hakkarainen et al., 2004), and additional tools used for knowledge-sharing such as email (Lingard, Pirzadeh, Blismas, Wakefield, & Kleiner, 2014) or meetings (Nicolini et al.,

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Furthermore, methods solely examining the contents of databases often fail to recognise that different groups may use information on incidents in different ways (Murphy et al., 2018b). In general, the methods employed in these studies on databases built upon notions that an information repository can be used to connect people and induce learning if its contexts are of a high quality. However, as noted in Chapter 2, one important aspect of communication is how workers make sense of the information that they receive and how they connect it to their own work. This aspect of LFI was not considered in any of the theoretical frameworks of studies investigating communication using databases prior to this thesis, and hence was not reflected in the methodological execution.

A different approach to researching information-exchange in LFI was taken by Gressgård & Hansen (2015). They theorised that since external contractors work across teams in an organisation, contractors could become ambassadors for distributing information informally. They postulated, however, that this knowledge-exchange process would only be effective if the contractors had a good relationship with the organisation which had hired them. To test this hypothesis, questionnaires were sent to a drilling organisation and its main contractors to assess the strength of relationship between the two organisations, how well workers felt information was exchanged, and how well workers felt they learnt from incidents. Statistical analysis was then employed on 2,653 responses to their survey to examine whether the hypothesis could be supported. The strength of this approach was its ability to find statistically significant evidence to support a link between information-exchange and LFI. However, LFI was measured in a relatively crude way, being only a single item on the questionnaire. As discussed in Section 2.3, the LFI process contains many elements and the validity of reducing it to a single item could be questioned (Littlejohn et al., 2017; Lukic et al., 2012, 2010). Additional limitations of the study included being based purely on the opinions of workers, and not unpacking how information was exchanged, what the purpose of exchanging information was, or how the informal networks complemented more formal information-exchange procedures. In comparison to the studies of databases, the theoretical underpinning of the method was clear. However, the theoretical basis still did not account for several network dynamics.

To the best of my knowledge, no study to date has holistically examined the use of networks in LFI. Moreover, while research has focused on practically useful issues, such as how to ensure quality in records of incidents (Jacobsson et al., 2010), there have been limited explicit theories of learning through networks on which methods were built. Broadening the scope of context beyond LFI, social network analysis (SNA) has been used in both safety-related studies and professional learning to gain insight into information distribution and use. For example,
Alsamadani et al. (2012) utilised SNA techniques to demonstrate how communication around safety influenced accident rates. Other studies have looked at how social networks can influence team dynamics, such as team flexibility (L. Zhang, He, & Zhou, 2012), willingness to express ideas (Venkataramani, Zhou, Wang, Liao, & Shi, 2016), knowledge-sharing (Allen, James, & Gamlen, 2007; Palonen, Hakkarainen, Talvitie, & Lehtinen, 2004), and professional development practices (Rienties & Kinchin, 2014). In addition to its ability to focus on networks in a broader manner than previous studies in LFI, it is a framework with a wide variety of well-developed theories that have led to corresponding methods being built upon the assumptions of those theories. SNA was therefore selected as a framework with which to address RQ1.

3.2 Social Network Analysis

SNA is an approach that incorporates multiple theories related to the importance of relationships (Burt, 2004; Lin, 2005; Palonen & Hakkarainen, 2014). The following section presents an overview of the two most relevant SNA theories to learning in the context of LFI.

3.2.1 Weak and Strong Links

One of the basic premises in SNA is that the structure of relational ties is a meaningful property that affects people’s behaviours (Knoke & Yang, 2008). One reason the relational structure of a network is conceptualised as important is that it can dictate how information, resources, or ideas diffuse across a network (Borgatti & Lopez-Kidwell, 2015). This network flow is then linked to concepts like innovation or productivity (Burt, 2004).

One SNA theory, proposed by Granovetter (1973), discusses strong and weak ties and the different roles they play in networks. A strong tie is understood to be a tie between two people who have a robust relationship; for example, two professionals who see each other every day, or two close friends who trust each other (Carolan, 2013). Conversely, a weak tie exists between two individuals, known as “actors” in social network theories, who interact either infrequently or in a relatively superficial manner (Daly & Finnigan, 2011). In studies using SNA, the strength of a relationship is usually judged either on frequency of interaction or perceived strength of the relationship by actors (Knoke & Yang, 2008).

Granovetter (1973) proposed that weak ties were vital to networks for several reasons. One key observation was that innovation usually occurs initially by people at the periphery of a network, as these actors are less strongly held to social norms. Another proposition of
Granovetter’s theory was that weak ties usually connected different groups, and that the removal of such a link would potentially restrict the flow of any kind of resource or information between the groups, an idea that will be revisited in Section 3.2.2.

Strong ties, on the other hand, have been theorised to be important in the exchange of both tacit and complex information (Hansen, 1999). Nonaka and Takeuchi (1995), for example, described a case study where the designer of a bread machine needed to work alongside traditional bakers to understand the complexities of the bread-making process. The knowledge possessed by the traditional bakers was not explicit, and so could not be passed along in verbal or written formats to weak ties. Nonetheless, strong ties have at least two drawbacks: their maintenance requires the investment of resources, such as time, and they can constrain the actions of actors who do not want to risk breaking the tie (Hakkarainen et al., 2004).

3.2.2 Structural Holes
A second important SNA theory that builds upon the notions of weak and strong ties is the concept of structural holes (Borgatti & Lopez-Kidwell, 2015). Granovetter (1973) proposed that only weak links could ‘bridge’ two relatively unrelated groups: if an actor has strong links between two groups it is likely that two of the actor’s strong links are mutual acquaintances. For example, if a PhD student in one institution has a strong relationship with a PhD student in another, then it is likely that over time they will build multiple connections with the other’s colleagues. At that point, their link is no longer the only one bridging the two institutions. However, Burt (2004) suggested that the key focus of this bridging function should not be the strength of the tie, but rather that it is non-redundant, i.e., that there are no other ties that could be considered structurally equivalent. In this view, an actor who links two groups is considered to occupy a structural hole; in other words, if that actor were removed from the network the groups would no longer be connected. The individual acting as a bridge would potentially have the ability to mediate and control the flow of information, resources, opportunities and so on between the groups (Hakkarainen et al., 2004).

The original context of structural holes was in enterprise, where Burt (2004) presented structural holes as beneficial, as it meant that the actor who held a bridging position had access to the resources of two groups and was therefore in a privileged position from the perspective of competition. However, empirical studies have questioned whether this is true, finding evidence that for innovation it is better that your connections are themselves collaborating (Ahuja, 2000). Structural holes are an interesting feature of network structures, but require contextual
knowledge to be able to interpret either as a competitive advantage or as a pinch point for communication.

The importance of structural holes has a strong connection to the “hub and spoke” model, often discussed in areas such as transport. In the hub and spoke model certain locations or actors become “hubs”, connecting many other locations or actors (Elhedhli, 2005). Resources will flow through these hubs and connect to all relevant others. The hubs can be considered as occupying structural holes, and create an efficient model of resource distribution, where there is little redundancy. However, as described above, while this lack of redundancy is beneficial from the perspective of cost in transportation, contextual factors are highly influential in the model’s capability to control the flow of information intended to affect behaviour (Calefato & Lanubile, 2016). This system can create vulnerabilities, as groups may be cut off from resources if the hub is incapacitated. For example, if a key person that acted as a hub in an organisation became sick or left the organisation, then some groups would have less information available to them when making decisions.

3.3 Limitations of Social Network Analysis

While being rich in both theory and methods related to relationships, SNA nevertheless has several limitations. Borgatti et al. (2009) and Emirbayer and Goodwin (1994) both highlighted the fact that, while SNA can add structure and precision to relatively vague concepts such as trust, it lacks tools, either theoretical or methodological, to unpack the cultural context in which those relationships exist. Likewise, Scott (2012) highlights that the lack of cultural consideration can lead the results of studies using theories of networks to seem interesting but lacking significance, leading the reader to ask, ‘so what?’.

While SNA is a useful collection of theories and methods to address RQ1, cultural context is key to the subsequent research questions. An additional theoretical framework was therefore required to address RQ2, RQ3a, and RQ3b. In addition, the framework needed to be compatible with SNA to allow for a holistic understanding of LFI and the functions of networks.

3.4 Selection of a Framework for RQ2, RQ3a, and RQ3b

Several studies have explored perceptions of LFI. However, these studies have mainly focused on specific individual aspects of the LFI process, such as possessing individual agency to engage with LFI (e.g., Haw et al., 2014; Lukic et al., 2012). Perceptions have also been explored from a cultural
perspective. Espin, Wickson-Griffiths, Wilson, and Lingard (2010), for example, explored the way that cultural and historical factors influenced people’s views on LFI, and subsequently how two departments in one hospital used the same LFI system differently. Other studies have demonstrated the importance of social influences on how people feel they should be learning via the LFI process. Catino and Patriotta (2013) used a theoretical framework based on cognition and emotions to understand the influence of a group’s safety culture on how they made sense of incidents.

RQ3a and RQ3b, conversely, require a holistic understanding of the environment and context in which learning is taking place rather than just a focus on perceptions. Several theories that have formed the basis for research in professional learning were considered to inform a theoretical framework to address RQ2, RQ3a, and RQ3b. Table 3 presents an overview of the different theoretical frameworks considered.
### Table 3 Theoretical frameworks considered

<table>
<thead>
<tr>
<th>Theory</th>
<th>Description</th>
<th>Advantages</th>
<th>Suitability</th>
</tr>
</thead>
<tbody>
<tr>
<td>Communities of practice</td>
<td>Communities of people learning by working together to achieve their goals (Wenger, 1998)</td>
<td>• Aligns with SNA</td>
<td>Suitable for RQ2, RQ3a, but may not identify organisational barriers for RQ3b</td>
</tr>
<tr>
<td>Agency</td>
<td>Individual identity and environmental factors affect a person’s belief in their ability to influence their own professional circumstances, which subsequently dictates their actions (Eteläpelto et al., 2013)</td>
<td>• Considers the interplay between individuals and organisations</td>
<td>Suitable for RQ2, RQ3a, and RQ3b, but no clear way to integrate with SNA except through narrative comparison of results</td>
</tr>
<tr>
<td>Self-regulated/socially-regulated learning</td>
<td>Individuals and groups are responsible for regulating their learning through means such as setting goals and reflection on past tactics (Hadwin, Järvelä, &amp; Miller, 2011)</td>
<td>• Considers informal and formal learning</td>
<td>Suitable for RQ2, RQ3a, but may not identify organisational barriers for RQ3b</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Many verified instruments</td>
<td></td>
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<td></td>
<td></td>
<td>• Has been used in prior studies on workplace learning</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Considers reflection, motivation and confidence</td>
<td></td>
</tr>
<tr>
<td>Model</td>
<td>Description</td>
<td>Advantages</td>
<td>Disadvantages</td>
</tr>
<tr>
<td>--------------------</td>
<td>-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------</td>
<td>--------------------------------------------------------------------------------------------------------------------------------------------------------</td>
<td>----------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>SECI Model</td>
<td>A cycle in which tacit knowledge becomes explicit, which then generates more tacit knowledge (Nonaka &amp; Takeuchi, 1995)</td>
<td>• Considers informal and formal learning</td>
<td>Not suitable for RQ2</td>
</tr>
<tr>
<td>Mimetic learning</td>
<td>People learn by being in an environment, watching, and making decisions (Billett, 2014)</td>
<td>• Based on experiential learning which has been used in LFI multiple times • Reflection is a key part of the theory</td>
<td>Suitable for RQ2, RQ3a, but may not identify organisational barriers for RQ3b</td>
</tr>
<tr>
<td>Activity theory</td>
<td>Individuals exist within a community which is trying to achieve objectives. Their activity to achieve these objectives is mediated by tools, rules, and the way labour is divided (Engeström, 2000b)</td>
<td>• Connects individuals, networks, teams, and organisations • Methods to investigate contradictions • Aligns well with SNA</td>
<td>Suitable for all RQs and SNA can be considered as related to the division of labour</td>
</tr>
</tbody>
</table>
After reflection on different common theories used in research on workplace learning, activity theory was selected. The theory was the only one that fit naturally with SNA, as it bridges the different levels of individuals, teams, networks, and organisations (Engeström & Kerosuo, 2007), and had been used to explore underlying barriers (Kaatrakoski, Littlejohn, & Hood, 2017). Activity theory is not without limitations, but given the research questions it allowed for triangulation of various data sources in a meaningful way, and allowed exploration of learning at a variety of levels.

### 3.5 Activity Theory

Activity theory is a culturally oriented framework that describes the activity of a group collaborating to achieve objectives (Engeström, 2001). The theory has origins in the work of Vygotsky (1978, 1986) who observed the mediating role that artefacts, such as signs and tools, can play in the achievement of objectives, as well as in the development of individuals. This was expanded upon by scholars such as Leont’ev (1974) and Engeström (1999), who noted that the activity of an individual rarely takes place in complete isolation from others, and is additionally mediated by several factors related to social context.

Activity theory is usually described as evolving through several generations that progressively considered social dynamics in more explicit terms. In the third and most recent generation of activity theory, an activity system is described as comprising of six elements (Roth & Lee, 2007). Three elements are inspired by the original ideas of an individual achieving goals in mediated activity: subjects (i.e., individuals in the system), artefacts (i.e., tools and signs), and objects (i.e., the objectives and goals of the activity) (Nardi, 1996). The socially-oriented elements of an activity system are the community who are collaborating, the division of labour within that community, and the rules governing the community (Wilson, 2014). In essence, the rules, tools, and roles of a group mediate how an individual and their community achieve their objectives (Issroff & Scanlon, 2002). The third generation of activity theory, however, also takes into consideration that there can be interaction between multiple activity systems in a network like configuration (Engeström, 2000b). The interactions between these activity systems influence the way in which activities are enacted, often resulting in the re-negotiation of the desired outcomes of each system (Engeström, 2008a). An illustration of the third generation of activity theory is shown in Figure 2.
It is worth noting that the term object has been used in subtly different ways in activity theory literature. Sometimes it is used as a particular physical or conceptual object on which activity is focused, and can itself be altered by an activity (e.g., Jonassen, 2000). Alternatively, others describe the object as the objectives of the activity (e.g., Nardi, 1996). Perhaps the best way of understanding the object is as outlined by Engeström (2000b), where the object is the physical or conceptual focus of the activity, but its importance comes from the fact that it becomes a manifestation of the overall objectives and goals of the activity system. As it is the goals and desired outcomes of a community that really drive how an activity is enacted, object is considered as synonymous with objective in this thesis. As with object, slightly different terms have been used to describe the mediating artefacts central to activity theory. Roth and Lee (2007) refer to the ‘means’, Engeström (2001) talks about ‘mediating artefacts’, while Larsen et al. (2017) specifically labels this part of the system ‘tools’. As this thesis does not delve into different use of sign, the term tools is usually used as the most relevant of the mediating artefacts.

Activity theory has developed from a deep philosophical tradition, and several key concepts beyond those described in the preceding paragraphs must be unpacked. One important principle is that activity systems evolve over time, for example, as objectives change or new tools become available (Roth & Lee, 2007). This developmental journey can introduce contradictions into a system, as, for example, the division of labour of a community is no longer appropriate for the tools available (Engeström, Virkkunen, Helle, Pihlaja, & Poikela, 1996). However, these tensions and contradictions are also the driving force for the development of activity systems. It is through addressing tensions and undertaking drastic changes that the possibility exists for expansive transformation, i.e., updating objectives and intentions in order to adapt to a changing environment (Engeström & Sannino, 2010).
Engeström (2001) outlined five principles of activity theory on which any methodology should build. Firstly, an activity system is the basic unit of analysis. An activity system is a stable system that reproduces itself over time. For example, in the case of LFI, every new incident alert that is disseminated will cause a set of actions to be generated. Secondly, each activity system is multi-voiced. In other words, the activity system is comprised of many individuals who will each carry their own perceptions and opinions based on their experiences. However, ultimately all the members of the activity system will be working towards achieving the same objectives. Thirdly, an activity system is continually evolving and historically placed. Consideration of the history and context of an environment in which the activity system exists is therefore important. Fourthly, as the activity system develops and changes, contradictions will naturally arise. For example, a tool may change causing the division of labour to no longer be appropriate, such as the introduction of new finance software packages that cause the accounting department of an organisation to be too large. Contradictions of this nature can cause difficulties but are also the source of innovation. Finally, activity systems will incrementally improve and develop over time, but will occasionally require truly transformational development to overcome contradictions. This is reminiscent of the notions of single- and double-loop learning discussed in Section 2.3.4 (Argyris & Schön, 1996). The activity system will make incremental improvements, i.e., single-loop learning, but occasionally the principles on which the whole system is built must be assessed to enable the system to transform, i.e., double-loop learning. In activity theory this transformation is viewed specifically as a re-conceptualisation of the objectives of the system (Engeström & Sannino, 2010).

Many of the requirements and considerations for research based on activity theory arise from the way in which knowledge is envisaged within the framework. Knowledge has been conceptualised in educational research in a variety of ways by researchers. For example, researchers in organisations have considered knowledge to be consist of information and skills, both explicit and tacit, possessed by workers (Nonaka & Takeuchi, 1995). Other scholars have emphasised the social nature of knowledge, as knowledge becomes embedded in routines, tools, and shared world models, rather than existing solely in the head of an individual (Säljö, 1999). In their article Blacker, Crump, and McDonald (2000) postulated that in activity theory knowledge is closely aligned with this second view. In terms of the principles of activity theory, this aligns well with the idea that an activity system is multi-voiced, and involves creating a negotiated understanding of the world manifested in mediating elements such as tools and the rules of a system.

In response to Blacker et al., Engeström (2000a) furthered the discussion around knowledge and activity theory by considering different epistemological views of an individual’s
actions. Engeström postulated that in activity theory knowledge is a temporal and developmental entity, in other words, constantly changing. Furthermore, it is not only the perceptions and routines of groups that influences knowledge, but rather knowledge needs to be considered in the context in which the activity system is situated. This is illustrated in the article by considering an umpire calling a ball as ‘out’ in baseball. You could consider the declaration as a representation of reality; the ball was out because it was physically outside the defined area that the pitcher could throw a good ball within. Alternatively, you could consider that the ball was out because it looked like it was out to the umpire – in other words there is an element of subjectivity in the knowledge that the ball was out. A third perspective is that the ball being out is a socially constructed norm: the concept of being out only has meaning because of the rules of baseball, personified in this case by the umpire. Engeström (2000a) asserts that in activity theory the knowledge that the ball is out must be taken within the context of the wider society. For example, perhaps the ball was out not because the umpire was following the socially defined rules, but because the umpire had been paid by book-keepers to let one side win. In other words, the umpire is not just influenced by the rules within the activity system, but the wider social context in which the activity system exists. This means that knowledge is not just contextual based upon the rules and environment of the activity system, but the broader historical and cultural moment in which the activity system is located.

3.6 Combination of Social Network Analysis and Activity Theory

SNA and activity theory are both frameworks that can give great insight into the dynamics of groups. Some similarities exist as the two frameworks can each be thought of as a collection of theories that focus on a particular aspect of a situation, with associated methods of inquiry. Research designs utilising SNA will place relationships at the heart of their study, whereas studies using activity theory explore how a community works together to achieve their aims. Each approach can be operationalised in a variety of ways, making both frameworks flexible tools with the ability to be tailored to address specific research questions. The strong influence of theories on each approach creates clear methodological considerations that must be taken into account by any research design incorporating either. While neither approach offers a prescribed step by step process to investigating a phenomenon, these explicit requirements make it easier for researchers to make the necessary move from theoretical stance to research design (Twining, Heller, Nussbaum, & Tsai, 2017).
While SNA and activity theory have evolved from very different schools of thought, they share a common understanding of the importance of the social, and the way that different networks can influence each other. The dynamics of the community and division of labour elements of activity theory in particular have an affinity with social network theories. Structural holes, for example, is a theory that could play a role in explaining both community dynamics and division of labour. Furthermore, the two interacting activity systems could be considered as two connected networks. Concepts from network theories, such as bridges, could be utilised to understand the interplay between the activity systems (Burt, 2004).

An additional aspect that aligns well between SNA and activity theory is the importance of history. In activity theory it is understood that there could be contradictions between, for example, how an artefact is used and the objectives of a system (Roth & Lee, 2007). Contradictions are given importance in the theory as it is by overcoming tensions that development occurs. These contradictions are often influenced by historical factors. For example, the traditions of the workplace in Japan mean that fax machines are still commonly used for communication (Fitzpatrick, 2015). This could be a potential tension when working with international partners who no longer use fax machines. This dynamic nature of communities and networks is also a central component in many studies utilising SNA. For example, SNA research designs can aim to understand how interventions influence network compositions over time (e.g., Rienties, Johan, & Jindal-Snape, 2015a).

3.7 The 3-P Model of Learning

While SNA and activity theory represent two compatible frameworks that are suitable for addressing the research questions to be considered, there remains a gap in the theoretical framework of this thesis: how is learning conceptualised. As outlined in Chapter 2, a multiplicity of theories have been used to conceptualise learning in studies of LFI; while the idea of learning has been central to many studies, none have offered a complete definition of what is learning in this context (Margaryan et al., 2017).

Furthermore, several articles did not define what is encapsulated by their views of learning but have attempted to measure it by evaluating changes that have resulted from LFI, considering these changes as evidence of learning. These studies usually employed a coding scheme to evaluate the written records produced after an accident investigation to evaluate the quality of changes induced (e.g., Braut & Njå, 2013; Jacobsson, Ek, & Akselsson, 2011, 2012; Okstad, Jersin, & Tinmannsvik, 2012; Reiter-Palmon et al., 2014; Stackhouse & Stewart, 2016). The
criteria that each research group used to evaluate the quality of learning that had taken place, nonetheless, differed significantly across studies. Stackhouse and Stewart (2016), for example, considered whether recommended actions had been carried out, and whether the recommendations addressed deep or superficial issues. Braut and Njå (2013), conversely, explored the content, context, and commitment of accident reports in order to assess learning.

Clearly there are a variety of different ways that learning can be operationalised and assessed in LFI. In this thesis learning will be conceptualised in line with the 3-P model of workplace learning (Tynjälä, 2013). The model outlines learning in the workplace as consisting of three parts: presage, process, and product. Presage represents the learner factors and the learning context. Examples of learner factors would be prior knowledge, ability, and agency. Examples of learning context would be organisational structure or manager support. Process relates to the activities in the workplace that are undertaken to support learning, such as participating in networks, formal training, or doing the job itself. Finally, products are the expected outputs of learning, such as understanding, creative solutions, or improved productivity. Figure 3 shows a diagram of the 3-P model of workplace learning with a few examples of each part.

![Diagram of the 3-P model of workplace learning](image)

*Figure 3 The 3-P model of workplace learning (modified from Tynjälä (2013))*
The model was chosen to conceptualise learning in this thesis for two reasons. Firstly, the model is a modification of that proposed by Biggs (1993, 1994). Biggs (1994) proposed his framework of learning as one with a practical focus; it aided teachers in taking a broader perspective of learning than just the results of tests, but was not too complex as to become unintelligible to a non-academic audience. This has similarities to the current situation of LFI, where many researchers are focusing on the outputs produced by LFI without considering other aspects of learning (e.g., Braut & Njå, 2013; Jacobsson et al., 2011, 2012; Okstad et al., 2012; Reiter-Palmon et al., 2014; Stackhouse & Stewart, 2016).

Secondly, the conceptualisation of learning chosen in this thesis needed to be flexible enough to encompass the previous work focusing on the individual, team, network, and organisation level of learning. The 3-P model incorporates individual concepts, such as agency, both as learner factors and as potential products (Tynjälä, 2013). Team and network factors are also considered in the process and learning context elements. Finally, from the organisational viewpoint, the model includes aspects that specifically deal with organisational support and change in learning context and products. In organisational learning Argyris and Schön (1996) proposed that learning could be both a product and a process. The 3-P model is compatible with established canon in organisational learning, but expands it to include factors related to individual and team learning.

It should be noted that the conceptualisation of learning in this thesis therefore focuses on learning as an outcome, in other words, “what have I learnt”, and learning as a process, “what am I doing to learn”. These concepts of learning align with the product and process parts of the 3-P model respectively. The presage elements of learner factors and learning context in the 3-P model are themselves not considered learning. However, as they impact both learning as a process and as a product they are investigated in this research.

3.8 Social Network Analysis, Activity Theory and Learning

While activity theory does not explicitly consider learning, it has evolved from the socio-cultural tradition, building on the work of Vygotsky (1978, 1986). In this paradigm individual learning is enabled by others: either through direct discussion or using artefacts embedded with cultural knowledge (Mercer, 2013; Säljö, 1999). Discussion in this tradition is a mechanism of learning, as understanding is developed first through interactions with others, before being internalised (Mercer, Dawes, Wegerif, & Sams, 2004). Conversation with people from different backgrounds in particular offers opportunities to benefit from individuals with substantially different experiences.
and knowledge base (Emerson, 1983; Hicks, 1996). Activity theory keeps a focus on group
dynamics by considering communities, the organisational context in which they are situated, and
how underlying contradictions can bring about transformational change of an entire system
(Engeström & Sannino, 2010). While activity theory does not specifically discuss the learning of
individuals, socio-cultural views of learning through group dialogue are a compatible way in which
learning takes place. This view of how learning occurs is also compatible with SNA, as the people
with whom you interact are dictated by your position in the network structure.

In summary, SNA and activity theory are compatible with the ideas of learning through
interactions and dialogue with others, although they are not necessarily explicit in this as the
mechanism for learning. However, research to date has shown that learning in the context of LFI
also needs to be able to take into account individual factors, such as agency (Lukic et al., 2013),
and organisational factors, such as processes (Hovden et al., 2011). The 3-P model of workplace
learning provides a flexible enough conceptualisation that any perceptions of learning that arise
when answering RQ2 can be accommodated. However, it should be noted that a predominantly
socio-cultural angle has been taken in this thesis due to the selection of activity theory and SNA as
primary frameworks.

3.9 Summary

Chapter 3 summarised the different theoretical frameworks that have been combined in this
thesis in order to address the research questions developed in Chapter 2. Combination of SNA,
activity theory and the 3-P model of workplace learning provide a comprehensive theoretical
framework that is appropriate to address the research questions of this thesis, and explicit in its
conceptualisation of learning. Chapter 4 will describe methodological considerations before
specifying the research design that operationalised the theories discussed in this chapter.
4 Methodology

Chapter 2 outlined the current state of research on learning from incidents (LFI), highlighting the key gaps in its conceptualisation as a learning process. Chapter 3 then considered suitable theoretical frameworks on which to make methodological decisions to address these gaps. Chapter 4 begins by describing the ontological nature of LFI. This understanding, combined with the theoretical frameworks in Chapter 3, forms the basis on which decisions about the research design of this thesis were taken. The chapter then ends with a description of the research design of the thesis.

As outlined in Chapter 2, the research questions addressed in this thesis are:

RQ1: How are networks used in LFI?

RQ2: What do workers perceive as successful learning in the context of LFI?

RQ3a: What beneficial practices in LFI enable learning?

RQ3b: What barriers to learning exist in the LFI process?

4.1 Ontological and Epistemological Considerations

Ontology can be understood as beliefs on the nature of the universe and reality (Twining et al., 2017). In research, this requires consideration of the nature of the topic of inquiry: is it an objective phenomenon, such as physiological measures, or is it subjectively defined by cultural norms and societal structures (Jupp, 2006). Ontological views can be thought of as on a scale moving from reality being viewed as a completely subjective entity, an interpretivist standpoint, to an objective and measurable world, a positivist standpoint (Bryman, 2016).

In this thesis the ontological nature of LFI must be deliberated in order to make suitable methodology decisions. As outlined by Argyris and Schön (1996), in organisations there is usually an official process that is outlined by procedures, the espoused theory of the organisation. In reality, however, the way that actions and tasks are carried out often vary between groups, as the

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written procedure is interpreted slightly differently depending on the group’s culture and history (Gherardi et al., 1998). This is known as the theory-in-use (Lukic et al., 2012). Previous research has shown that this is also true for LFI, as the way that systems designed to support LFI are used depends upon socially constructed norms (Rossignol, 2015; Rossignol & Hommels, 2017). In Rasmussen’s (1997) article on the difficulties modelling safety related processes, he postulated that this difference in implementation is influenced by several contextual layers, such as legal requirements and political pressures. Nonetheless, there are also aspects to the topic that could be examined from a positivistic standpoint, as the desired outcome of LFI is to prevent physical incidents. This diversity in ontological perspectives can also be observed when considering previous LFI studies, which have predominantly taken an interpretivist standpoint to explore subjective elements (e.g., J. E. Anderson et al., 2013; Catino & Patriotta, 2013). Nevertheless, a few studies have used statistical methods to explore the concrete outcomes of LFI as a learning process (e.g., Gilbey et al., 2015; Madsen et al., 2015).

When viewing the research questions through this ontological lens, LFI consists of socially constructed concepts mixed with some positivistic aspects. How information on incidents is distributed around an organisation, RQ1, for example, will have positivistic elements, as the paths which incident alerts take could be mapped out. Nonetheless, prior research on information-exchange in organisations has demonstrated that informal networks play a large role in how information travels and is influenced by more subjective concepts, such as trust (Hakkarainen et al., 2004; Palonen et al., 2004). Methods used to investigate RQ1 must therefore be capable of investigating both the objective paths through which information is communicated, and the informal and potentially tacit ways through which incident-information is additionally shared (Nonaka & Takeuchi, 1995).

In contrast, RQ2 revolves around perceptions of what is successful learning, bearing in mind that learning has been conceptualised in multiple ways (Paavola et al., 2004). Furthermore, what are considered enablers and inhibitors of learning, i.e., RQ3a and RQ3b, are likely to vary across individuals and organisations, depending on how they define successful learning in RQ2. Methods to address RQ1 should be capable of capturing both objective and subjective elements of networks. Methods addressing RQ2, RQ3a, and RQ3b need to be capable of exploring perceptions and subjective realities.
4.2 Mixed Methods Research

Mixed methods involve the use of both quantitative and qualitative data, at potentially multiple points in a research design (Johnson, Onwuegbuzie, & Turner, 2007). Before delving into method selection and research design, it is worth noting that some consider there to be epistemological issues surrounding the concept of mixed methods. Historically there have been many debates between the value of quantitative and qualitative approaches to research, and the philosophies underpinning them (Johnson & Gray, 2010). Sometimes called the ‘incompatibility thesis’, it has been suggested that qualitative and quantitative approaches to research are incompatible due to these differences in ontological and epistemological philosophies (Howe, 1988); qualitative research is usually associated with interpretivist standpoints, while quantitative research usually aligns itself with a positivistic philosophical base (Bryman, 2016). Mixed methods research, in contrast, is often described as building on the pragmatic philosophy (Creswell, 2015; Johnson et al., 2007). Pragmatism is a philosophy that embraces several principles, rather than building from a positivist or interpretivist starting point, on how knowledge exists and can be known. Perhaps most fundamentally it rejects the notion of dualistic paradigms, e.g., that research must be either objective or subjective (Biesta & Burbules, 2003). Additionally, it embraces research that is oriented towards addressing problems rather than building systems (Bietsa, 2010). It has been noted that both qualitative and quantitative approaches to research contain subjective and objective elements, and in fact have much in common (Johnson & Onwuegbuzie, 2004). For the research questions under investigation in this thesis neither a purely positivistic nor interpretivist approach would suffice. Pragmatism provides a philosophical basis for mixed methods, seeing either all methods as valid just differing in generalisability (Bietsa & Burbules, 2003), or mixed methods as different ways of presenting a variety of perspectives on the research subject (Fetters, Curry, & Creswell, 2013).

Given that mixed methods are a valid form of inquiry, several practical issues arise that must be addressed in a research design. There have been several authors who have proposed typologies of mixed methods (Creswell, Plano-Clark, Gutmann, & Hanson, 2003; Leech & Onwuegbuzie, 2009; Teddlie & Tashakkori, 2009). One of the common themes across typologies is the order in which data is collected. Data can either be collected sequentially or concurrently (Creswell, 2015). A sequential design offers the advantage that research phases can build on each other, for example by attempting to explain quantitative results using a follow-up qualitative approach (Ivankova, Creswell, & Stick, 2006). However, concurrent data collection can allow for data triangulation and minimising bias (Johnson et al., 2007). I thus carefully considered the order
of data collection during the design of this research project, specifically, how different methods could build upon each other and their fit into the wider theoretical framework.

Another consideration of mixed methods designs is the relative importance assigned to qualitative and quantitative methods. Deciding which methods to give priority to, or indeed whether to give equal weight to both methods, should be driven by the types of research question of interest (Leech & Onwuegbuzie, 2009). Different research designs may include features such as nesting one method within another (Creswell, 2015). It may also include a transformative element, based on the integration of approaches such as action research or design based research (Creswell et al., 2003). A practical challenge that is often raised when conducting mixed methods research is the time required compared to designs employing a single method (Ivankova et al., 2006). This constriction of time may lead to the need to prioritise one type of method over another. In the case of this thesis, an emphasis was given to qualitative data collection methods, as all research questions involved perceptions to a certain extent.

Data integration is perhaps the biggest challenge of mixed methods research: how can separate methods be combined meaningfully in a way that is more than simply two parallel studies (Yin, 2006)? Data triangulation, i.e., comparing different data sources, has been suggested as a way of to increasing understanding of a phenomenon in mixed methods research (McKim, 2017), and increasing research rigour in general (Twining et al., 2017). Triangulation in this way may produce interpretations from different methods that confirm or contradict each other, but either way will expand the researcher’s understanding of a topic (Johnson & Onwuegbuzie, 2004). In addition, mixed methods can be employed at points in the research design besides the analysis phase to achieve integration. For example, mixed methods can be used in the design section of the research to select particular cases (Sharp et al., 2012), or an intermediate state in a sequential study where initial results drive the design of subsequent inquiry (Fetters et al., 2013). Regardless of how the different data sources integrate, their interaction should add rigour and increased understanding to a mixed methods design.

Perhaps the most challenging aspect of designing, and subsequently reporting, a mixed methods research study is clearly understanding and outlining how the different methods mix. A visualisation has been suggested as a way to both aid in designing a mixed methods study, but additionally to facilitate readers in understanding how data was collected and combined (Creswell, 2015). Ivankova et al. (2006) suggested a series of rules for drawing diagrams representing mixed methods procedures, such as using capitalisation to demonstrate relative importance of qualitative and quantitative data, and detailing both procedures and outputs of each stage.
In summary, a mixed methods research design should:

- Specify sequence of data collection
- Discuss relative importance of qualitative and quantitative methods
- Consider data integration, potentially at multiple points
- Provide a visualisation of the procedure

All these requirements for the research design of this project will be detailed in Section 4.9.

### 4.3 Case Studies

Although there appears to be a strong case for the use of mixed methods, a more specific approach was required that would allow the operationalisation of the theoretical frameworks discussed in Chapter 3, and the integration of different types of data, in line with mixed methods designs. As all research questions required the investigation of perceptions, I considered framing the thesis around one of the dominant qualitative approaches (Creswell & Poth, 2013). Grounded theory, which develops theory from data rather than designing instruments building on theoretical frameworks (Strauss & Corbin, 1998), is one approach to qualitative inquiry. Although grounded theory has been used in the context of LFI (Koehn et al., 2016), I felt that there was a lot of insights to be garnered from the results of studies to date on LFI, methodological choices made by those studies, and the wider literature on professional learning. In particular, as outlined in Chapter 2, a multiplicity of theories have been used to conceptualise LFI, and I decided to build upon and integrate theoretical perspectives rather than create my own. I also considered narrative, ethnographic, and phenomenological approaches (Creswell & Poth, 2013). Narrative approaches focus on the experiences and stories of individuals (Ayres, 2008). Ethnography involves in-depth observation and potentially participation in a community (Fetterman, 2008). Phenomenology explores the perceptions of a specific group on a phenomena (Giorgi, Giorgi, & Morley, 2017). I deemed these approaches unsuitable due to being likely to generate very focused data that would not be compatible with the more holistic views of activity theory, which as described in Section 3.4, was selected as part of the underpinning theoretical framework of the research design.

The final approach I considered was case studies (Creswell & Poth, 2013). Case studies allow for the combination of multiple methods, using either quantitative or qualitative data, and are suitable when in-depth knowledge of a social situation is required to answer research
questions (Baxter & Jack, 2008; Yin, 2013). In this project a case study design would allow data from qualitative sources exploring perceptions to be combined with social network analysis (SNA), and potentially other methods. This could examine not just how information was shared around an organisation and what those involved in the LFI process perceive to be successful learning, but also the organisational context in which LFI took place. Furthermore, case studies have frequently been used with both SNA and activity theory (Allen et al., 2007; Issroff & Scanlon, 2001). Moreover, as shall be discussed below, important considerations such as approaches to data integration or boundary definition are common across SNA, activity theory, mixed methods research designs, and case studies (Murphy, Littlejohn, & Rienties, 2020). This meant that case studies were both theoretically and methodological compatible with the frameworks and approaches discussed in this thesis.

One important consideration in case study design is the identification of cases (Creswell & Poth, 2013). This includes the type of case to be considered. Stake (1995) proposed that a case should represent either an illustrative example of a phenomenon or be an unusual situation with intrinsic value. Yin (2013) also supported case studies being used to explore either exemplary or extraordinary examples of a phenomenon, but suggested three additional types: critical cases to test theories, revelatory cases to examine previously inaccessible phenomena, and longitudinal cases to examine how a phenomenon changes over time. In this thesis, as the research questions were primarily of an explorative nature, I decided illustrative cases of organisations with established routines and systems to support LFI were necessary. Later research could therefore build upon the results of this thesis with more unusual cases of intrinsic value.

Whether a study comprises a single or multiple cases is also a consideration (Chmiliar, 2009), and in a design with multiple cases how many are required (Royer, 2009). The research questions and aims are of vital importance for all choices related to case selection, and decisions surrounding the type of cases, the number of cases, and even the boundaries of the phenomenon (Sharp et al., 2012). Despite this, practical restrictions can also restrain case availability (Stake, 1995), and so selection must be a balance of rigour and practical restraints. As shall be discussed in Section 4.9, the number of cases selected in this thesis was based upon a collection of theoretically desirable requirements for organisations, combined with a practical limitation of how many organisations volunteered.

Data analysis can also pose a challenge to researchers utilising case studies, as multiple methods must be brought together to describe a larger phenomenon. Both Yin (2013) and Stake (1995) commented on the fact that there are no set paths for analysing case studies. This is similar to the requirements of mixed methods designs to consider how data will be integrated,
highlighted in Section 4.2 (Guetterman & Fetters, 2018). General strategies have been suggested, such as comparing data to the original theories on which the case study was designed, or contemplating rival explanations to explain data observed (Baxter & Jack, 2008). Often there is no genuine end point to data analysis in case studies, as there is always more literature that could be read to see the findings through another light (Harland, 2014). Like many forms of analysis that deal with qualitative data, case study analysis is an iterative process and should continue until a researcher is confident that the main meanings have been distilled (Braun & Clarke, 2006). The general details of the analysis approach in this thesis will be discussed below in Section 4.9.

4.4 Social Network Analysis

Some of the key theories associated with SNA were discussed in Section 3.2. Building on these theories there are a variety of quantitative and qualitative tools used to investigate the structure and nature of relationships within the SNA framework (Wasserman & Faust, 1994). SNA is conducted either at the ego- or the network-level of investigation (Hanneman & Riddle, 2005). Ego-level analysis focuses on the connections of individuals, with often no investigation of how alters (the connections named by a participant) are themselves linked (Crossley et al., 2015). Network-level analysis, conversely, focuses on how all members of a bounded group are connected to each other (Knoke & Yang, 2008). Techniques from both ego- and network-level analysis were used in this thesis. The overall structure of teams and networks provided valuable insight into the formal mechanisms through which information is shared, as well as identifying key actors, the SNA term for an individual, who bridged different groups. The ego-level analysis supplemented this with quantitative assessment of relationship diversity, and qualitative exploration of the observed patterns.

Network-level analysis requires the production of a matrix that contains numeric ratings or binary values of who is connected to whom (Carolan, 2013). An example of this kind of matrix is shown in Table 4. If Table 4 was generated by asking each person who they considered a friend, then Bruce Wayne would have indicated that he considered nobody a friend, as there are only zeros on his row. Peter Parker, on the other hand, did not consider Bruce Wayne a friend, but did indicate that Steve Rogers and Wade Wilson were, as shown by the ‘1’s in the column for each.
Table 4 Example of matrix with information on social connections

<table>
<thead>
<tr>
<th></th>
<th>Bruce Wayne</th>
<th>Peter Parker</th>
<th>Steve Rogers</th>
<th>Wade Wilson</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bruce Wayne</td>
<td>-</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Peter Parker</td>
<td>0</td>
<td>-</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Steve Rogers</td>
<td>0</td>
<td>1</td>
<td>-</td>
<td>1</td>
</tr>
<tr>
<td>Wade Wilson</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>-</td>
</tr>
</tbody>
</table>

The matrix shown in Table 4 can be converted into a diagram called a sociogram, which displays all the relationships in a network, an example of which is shown in Figure 4. In these diagrams, the arrows, known as edges, point from dots, known as nodes, depending upon who indicated whom. From the matrix in Table 4, Bruce Wayne indicated that he considered nobody a friend. In the sociogram there is therefore no arrows going from the Bruce Wayne node to any of the other nodes. Peter Parker indicated that he was friends with Steve Rogers and Wade Wilson, so there are therefore arrows going from the Peter Parker node in Figure 4 to the nodes representing these two people.

Figure 4 Example sociogram
In this case relationship ties between actors, i.e., people in the network, have been reduced to either ones or zeros, so a relationship is either present or not. While quantitative data is required to produce the matrix and perform many of the techniques associated with network-level analysis, it can be generated in a variety of ways. For example, name generator surveys would ask a participant to mark which people they have a certain kind of tie with (e.g., please indicate who from the following list you consider a friend) (Wasserman & Faust, 1994). Alternatively, SNA data can be gathered through observation of situations, noting who interacts with whom to create the matrix (Borgatti, Everett, & Johnson, 2018). Electronic records could also be mined to establish where connections exist, such as who is sending emails to whom (Knopke & Yang, 2008).

Ego-networks, conversely, are commonly explored through both quantitative and qualitative means. For example, studies have investigated ego-networks through quantitative instruments looking at the quantity of relationships (Rienties & Tempelaar, 2018) or the stability of relationships (Van Waes, Van den Bossche, Moolenaar, & Van Petegem, 2015). In these types of studies statistical tests are often used to compare differences in ties. However careful consideration must be paid to the types of tests utilised, as many statistical techniques require independence in the data set, which is not necessarily true when ego-networks of participants overlap (Crossley et al., 2015; Snijders & Spreen, 1995). This is illustrated by considering the friends of a married couple; there is likely to be a large group of mutual friends, hence the ego-network of one partner cannot be considered independent of the other partner’s connections. Qualitative approaches to ego-level analysis can be similar to non-SNA approaches, for example, asking participants to describe their experiences with a particular focus on their connections in a network (Hytönen, Palonen, & Hakkarainen, 2014). In mixed methods designs qualitative SNA methods often take advantage of the visual nature of quantitative methods, providing network visualisations to participants for reflection (Mittelmeier, Rienties, Tempelaar, & Whitelock, 2018; Rienties & Kinchin, 2014).

Despite its ability to explore both the qualitative and quantitative nature of relationships, several limitations exist within SNA. SNA has been criticised as being neglectful of the context in which ties and networks exist (Borgatti et al., 2009). In other words, SNA has multiple tools for unpacking how relationships change and exploring why particular patterns have been observed, however, it is usually supported by other research methods to understand why relationship dynamics are meaningful (Hollstein, 2014). Furthermore, it has been noted that SNA does not account for group influences such as culture, or individual factors such as agency (Emirbayer & Goodwin, 1994). While insufficient to address all the RQs of this thesis, either from a theoretical or methodological standpoint, it is important to consider how SNA is combined with other
methods. Approaches associated with culture and meaning making are often theoretically compatible with SNA, but encounter difficulties methodologically: SNA strips away cultural factors – especially in quantitative methods which reducing relationships to ones and zeros, while many methods used to study culture purposefully choose not to investigate network structures (Törnberg & Törnberg, in press).

4.5 Activity Theory

The theoretical basis of activity theory was discussed in Section 3.5. Researchers have operationalised activity theory in several ways: as the basis for an intervention (Engeström et al., 1996), as an analytical tool to describe working on a task (Jurdak, 2006), or as a guide to identify tensions and contradictions in an activity (Kaatrakoski et al., 2017). One of the most common ways that it has been used in research is as framework for data triangulation in case studies (Lazarou, Erduran, & Sutherland, 2017). Both mixed methods designs and case studies recommend use of analytical frameworks to aid data triangulation (Creswell et al., 2003; Yin, 2013), and activity theory can be a guide for bringing together different methods to create a cohesive picture of a situation (Shanahan, 2010).

As a framework in the socio-cultural tradition, dialogue is a key component of activity theory (Montoro, 2016). Language, along with tools, are understood to be cultural artefacts, endowed with cultural knowledge that has developed over time (Vygotsky, 1978, 1986). Analysis of dialogue and language use can therefore provide insight into the culture of a group (Postholm, 2015). In this vein, discursive analysis methods have been used in research designs based on activity theory. As outlined by Engeström and Sannino (2011), and discussed in Section 3.5, tensions and contradictions arise through historical influences and cannot be observed directly, but can be identified through analysis of their manifestations in language. For example, Kaatrakoski et al. (2017) explored the contradictions in educators’ engagement with open educational resources using a linguistic-thematic analysis. However, Engeström and Sannino (2011) criticised some approaches to identification of tensions in dialogue, as tension is an unprecise term. To address this potential methodological weakness, Engeström and Sannino proposed a classification system of discursive manifestations of contradiction, with the caveat that it was not intended as an exhaustive list of potential discursive manifestations. Table 5 presents descriptions of these different types of manifestations.
Table 5 Descriptions of different types of contradiction (Engeström & Sannino, 2011; Kaatrakoski et al., 2017; Postholm, 2015)

<table>
<thead>
<tr>
<th>Discursive Manifestation</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dilemma</td>
<td>The existence of multiple values or morals. These differences in perception of value may be inter- or intra-person.</td>
</tr>
<tr>
<td>Conflict</td>
<td>Dispute, resistance, or contention to the ideas or actions of others. Conflicts often involve situations where an individual feels the will of others are forced upon them.</td>
</tr>
<tr>
<td>Critical conflict</td>
<td>Critical conflicts resemble conflicts but are internal to individual. They can be conceptualised as an almost paralysing internal battle, often with feelings of guilt.</td>
</tr>
<tr>
<td>Double bind</td>
<td>Caused by situations in which individuals are presented only with unacceptable options due to the conditions of the activity system.</td>
</tr>
</tbody>
</table>

As with SNA, activity theory has several drawbacks. Firstly, while it is a framework that is capable of investigating the interplay between individuals, teams, organisations, and networks (Engeström & Kerosuo, 2007), it considers individuals through their objectives and environmental influences. Its methodological tools have not traditionally been used to investigate individually oriented components, such as emotion, identity, or cognition (Roth & Lee, 2007). Furthermore, as contradictions are unobservable and detected through their manifestations (Engeström, 2014), their interpretation is subjective. Studies to date have primarily employed qualitative methods as culture and perceptions form the core of activity theory (Postholm, 2015; Roth & Lee, 2007). There is therefore an opportunity to explore the value of quantitative methods in a mixed methods design that could add a more objective contrast to traditional qualitative data analysis techniques used in activity theory.

4.6 Mixed Methods Case Studies Using Activity Theory and Social Network Analysis

Despite potentially complementary views of the world from a theoretical perspective (see Section 3.8), activity theory and SNA differ in several significant ways. When using activity theory, the unit of analysis must be an activity system (Engeström, 2000), and the individuals involved in that activity form the boundary as to who is considered part of the community. Boundaries are therefore defined based on who largely possesses the same objectives, with some natural variation between subjects (Nardi, 1996). In contrast, in SNA it is often difficult to define a
boundary, and boundaries, which influence the unit of analysis, can often be considered dynamic (Knok & Yang, 2008). For example, in studies of ego-networks a single relationship could be considered as a meaningful unit of analysis (Borgatti et al., 2009). Alternatively, it may not be meaningful to define a network boundary at all, as people completely un-related in principal to an activity can have a strong influence. For example, the romantic partner of a CEO is likely to be a source of support and influence his or her work activity, but will to be missing from an analysis based on activity theory. Another difference is that activity theory places a large emphasis on the context and the objectives of a network. Some studies have focused entirely on the differing objectives of connected networks (e.g., Larsen et al., 2017). These differences must be considered in the design of a mixed method case study using both activity theory and SNA.

Besides potential conflicts in activity theory and SNA another difficulty of combining them in a mixed methods case study is the vast amount of terminology and assumptions that must be addressed in SNA, activity theory, mixed methods designs, and case studies. For example, Yin (2013) differentiates case studies based on the aims of the study: cases can either be critical, a common example, an unusual case, exploration of a previously inaccessible phenomenon, or longitudinal examination of a phenomenon. Likewise, mixed methods research has been divided based upon such criteria as the sequence in which data is collected (Creswell & Plano-Clark, 2011), whether one data source is nested within another (Creswell et al., 2003), or the relative importance given to quantitative and qualitative methods (Leech & Onwuegbuzie, 2009). Guetterman and Fetters (2018) suggested that when case studies and mixed methods are combined, they can be classified as either case study-mixed methods designs, i.e., a case study that utilises mixed methods, or mixed-methods case studies, i.e., a mixed methods study that has nested within it a case study.

It can be a challenge to master all the terminology associated with mixed methods, case studies, activity theory, and SNA. After consideration of the assumptions of all four approaches, the following factors were deliberated in the research design:

1. Sequence of data collection

This distinction is not usually made within case studies, but is an important consideration of mixed methods (Leech & Onwuegbuzie, 2009). Data for activity theory based studies is often collected over an extended time period, similar to ethnographic or grounded theory approaches (e.g., Engestöm, 2001). Methods for collecting SNA data vary, but observation techniques have commonly been used to determine where ties exist (Knok & Yang, 2008). This method of SNA data collection aligns well with concurrently collecting all data. Alternatively, if interviews are
used to gather information about elements of the activity system, it could be beneficial to send a social network survey first. SNA can be used to initially estimate boundaries for activity systems if there are uncertainties regarding the formal structures, such as work networks. Although as it is objectives rather than connections that define an activity system (Nardi, 1996), boundaries of activity systems should still be investigated through other methods. SNA results additionally could be used to identify interview participants, based on their position or role in the community, and can produce diagrams for reflection during qualitative inquiries (e.g., Mittelmeier et al., 2018).

2. Importance of each method

One common aspect of mixed methods typologies is the relative importance and relationship between qualitative and quantitative methods (Creswell et al., 2003; Leech & Onwuegbuzie, 2009). As SNA gives rich detail of the community and division of labour aspects of an activity system, SNA becomes nested within the broader activity theory-based case study. In their review of 81 articles, Guetterman and Fetters (2018) found 83% of studies combing case studies and mixed methods in their designs were primarily case studies that utilised mixed methods approaches. Nesting SNA in an activity theory-based case study would therefore be a natural way to mix the two frameworks. However, it could be that the case study is itself embedded in wider SNA research. Imagine a research project where the goal is to understand the variety in social structures of 100 classes in a school. Classes of interest could then be selected for further investigation using activity theory-based case studies as exemplars of certain situations. In this approach the case study would be embedded in broader SNA research.

3. Number and type of cases

The number and type of cases is always of fundamental concern in case studies (Yin, 2013), although practical restrictions may dictate that there are limited options (Stake, 1995). In general, it is necessary to consider whether the case you are choosing is typical of the phenomenon of interest, or a particularly unusual situation that gives insight into the phenomenon (Guetterman & Fetters, 2018). In the most rigorous approaches to case selection, mixed methods can be employed to select cases, which may include SNA data (Sharp et al., 2012). The number of cases that should be included in the study is also something to be deliberated. Royer (2009) suggests that the type of cases being examined should be a consideration, but the central driving force for the number of cases selected should be the goal of the research. As each case is a single unit of analysis (Engeström, 2001; Harland, 2014), whether the purpose of the research is to describe a situation, generate a theory, or test a hypothesis will dictate how many cases are appropriate. As
with data collection, the sequence of case selection may be something that a researcher needs to consider, as cases may be investigated concurrently or one after another (Chmiliar, 2009).

4. Boundaries

One key part of both SNA and activity theory is consideration of boundaries (Knoke & Yang, 2008). Nardi (1996) proposed that boundaries of activity systems can be defined by considering which individuals have similar objectives. Official job title and role has been used to differentiate boundaries of activity systems, such as students versus supervisors (Larsen et al., 2017). However, as outlined above, sequential designs offer opportunities to base decisions on activity system boundaries on the results of SNA. As an alternative, boundaries could also be drawn up in a sequential design after qualitative methods have been used to determine the similarity of objectives between communities.

5. Data integration

Data integration is a key concept in both mixed methods and case studies (Creswell & Plano-Clark, 2011; Yin, 2013). Depending on the exact research design integration could occur at several stages. A type of integration that may be appropriate in case studies combining SNA and activity theory is the weaving approach during reporting (Fetters et al., 2013). As activity theory can be conceptualised as six elements a narrative description of each, where all qualitative and quantitative sources of data are combined, should usually be possible. However, depending on the research questions being addressed, there are likely to be other opportunities, for example, building methodologically by using SNA to design qualitative interview protocols (Creswell & Plano-Clark, 2011). It is, however, vital that purposeful integration is considered as part of the research design.

Despite the combination of activity theory and SNA building on each other’s strengths, there remain limitations that are not addressed by this kind of research design. Perhaps the largest is the lack of focus of either methodology on individuals’ internal factors (Emirbayer & Goodwin, 1994). Furthermore, combination in the way suggested by this chapter is subject to many of the limitations that are inherent to case studies and qualitative research in general, such as limited generalisability (Creswell & Poth, 2013). Additionally, limitations that are common across mixed methods designs could become issues in this type of research design. SNA and activity theory are both broad frameworks which are associated with multiple methods; skills and knowledge related to both frameworks are required to effectively carry out a research project, and can be time consuming to develop (Creswell & Plano-Clark, 2011). Ultimately, like any
research design, the combination of activity theory and SNA is suitable in some situations. Affordances and limitations must be weighed against the specific research questions.

4.7 Interviews

Several studies on aspects of LFI have used semi-structured interviews to gather data on perceptions (e.g., Espin et al., 2010; Haw et al., 2014; Lukic et al., 2013). Other studies have used semi-structured interviews to explore the experiences of various participants in the context of LFI (e.g., Bauer & Mulder, 2007; Vastveit & Nja, 2014). All the research questions of this thesis have aspects that relate to either the experiences of individuals (RQ1 and RQ3a) or their perceptions (RQ2 and RQ3b). I therefore decided that semi-structured interviews were a suitable instrument that fit the context of LFI, as well as having a history of exploring perceptions of objectives within an activity theory framework (Jurdak, 2006; Mwalongo, 2016).

Interviews are a flexible method used in many qualitative approaches. Due to this flexibility several important decisions were made regarding the design of the interview, as the data produced was heavily guided by the questions asked. The first step in creating an interview protocol is understanding the subject area, and purpose of the interviews (Kvale, 2007). To this end a systematic literature review was undertaken to become familiar with the topic (see Murphy, Littlejohn, et al., submitted). After becoming familiar with the topic, and identifying specific research questions I decided that the interviews conducted as part of this thesis had four main aims:

1. Expand on the quantitative social network data with a qualitative understanding
2. Explore in depth the perceived objectives of LFI
3. Describe the six elements of an activity system in detail
4. Provide enough discussion that discursive manifestations of contradictions in the activity system could arise

A semi-structured interview script was therefore created. Semi-structured interviews allow a consistent structure to ensure the same areas are interrogated, but allow for flexibility to follow up on answers in a suitable manner (Gubrium & Holstein, 2002). In the creation of the interview instrument, which will be detailed in Section 4.9, it was important that the interview
protocol therefore was structured in a way to allow data to be collected to meet all four of these aims.

Interviews, like all social research methods (Creswell & Plano-Clark, 2011), have several limitations and weaknesses. One weakness that is often described is the subjectivity of interviews as a research tool (Bryman, 2016). Additionally, interviews are highly dependent upon the skills of the interviewer and the relationship that unfolds between the interviewer and participant (Gubrium & Holstein, 2002).

To address these weaknesses it is important therefore that studies using interviews have a high level of transparency on decisions made during the design process (Kvale, 2007), and that the interviewer is skilled in active listening (Rogers, 1957; Yeo et al., 2014). Other techniques such as data triangulation, method triangulation, or participant checking can add to the validity of interviews (Twining et al., 2017).

4.8 Validated Questionnaires
In order to address some of the weaknesses of the subjective nature of interviews, a questionnaire was incorporated into the research design. The learning from incidents questionnaire (LFIQ), is a previously validated instrument that asks respondents to rate on a scale of one (strongly disagree) to five (strongly agree) how well their organisation carries out various aspects that should be part of the LFI process (Margaryan et al., 2018). The LFIQ organises its questions against six phases of LFI described in Section 2.3 (Littlejohn et al., 2017), as well as additionally mapping to the five considerations of LFI proposed by Lukic et al. (2012, 2010). The questionnaire provided data to triangulate with interviews.

One of the strengths of questionnaires is that statistical tests exist in order to assess validity (Field, Miles, & Field, 2013). Nonetheless, although the LFIQ was validated statistically with 781 participants from two organisations (Littlejohn et al., 2017), it cannot be assumed that a survey validated in one context automatically is valid in another (Field et al., 2013). As large multinational oil and gas organisations were the subjects of both the initial validation of the LFI and this thesis, there is support for the use of the LFIQ in the context of this research. Nevertheless, some assessment of validity was required, such as calculating internal reliability with the use of Cronbach alpha for the proposed scales.

Validated questionnaires share a similar weakness to interviews in that they rely on self-report data. Self-report data can be unreliable due to dishonesty, biases or misconceptions by
participants (Donaldson & Grant-Vallone, 2002), and unlike interviews there is no relationship built between interviewer and respondent to establish trust and explore reasoning. Furthermore, some studies have demonstrated that respondents’ perceptions of a topic can differ to objective observation of behaviour (Catrysse et al., 2018). It is therefore beneficial that the LFIQ was triangulated with other methods that aims to uncover hidden truths, such as analysis of dialogue in line with activity theory.

4.9 Research Design

As recommended by Ivankova et al. (2006) visualisations of research designs are necessary in mixed methods approaches, as how various data sources are brought together through the research process can become complex. This is true in the case of this thesis which combined activity theory and SNA in a mixed methods case study design. Three types of data were collected in the research design. Figure 5 shows how these data sources mapped to the theoretical frameworks of SNA and activity theory, the types of analysis conducted, and ultimately the research question that each analysis addressed.
Figure 5 Research design mapped to research questions

Figure 6 shows the different phases of the research design in sequential order.
Figure 6 Research process, procedures, and products
Section 4.6 highlighted five considerations for this thesis: importance of each method, sequence of data collection, number and type of cases, boundaries, and data integration. As can be seen from Figure 5, the SNA analysis contributed to the activity theory analysis, and hence each case study could be considered as primarily an activity theory-based case study with nested SNA. As such the qualitative interview data was the primary focus of the thesis, with quantitative data provided by a social network survey and a validated questionnaire providing different perspectives for comparison.

The sequence of data collection and analysis can be seen in Figure 6. The quantitative data was collected first. It was necessary to collect the quantitative SNA data in order to create visualisations for the interviews, a technique that has been used in previous mixed methods SNA approaches (Rienties & Kinchin, 2014). As response rates tend to drop over the course of a research project, the validated questionnaire was distributed at the same time. The interviews therefore took place following collection of the quantitative data. However, I did not analyse the results of the validated questionnaire until later in the research process, to minimise my preconceptions which could influence how I conducted the interviews (Kvale, 2007).

Three cases were selected for inclusion in this thesis. Multiple case studies increase the rigour of research, as each case serves as a replication if methods are consistently applied, as they were in this thesis (Yin, 2013). As is described below, organisations were selected because they met a list of criteria and volunteered to be involved in the research, a practical consideration in the number of cases selected (Stake, 1995).

The selection of the boundary of the case was driven by the need to have the activity system as the unit of analysis (Engeström, 2000). The research questions aimed to unpack what happens when incident alerts are distributed around an organisation. This meant that front-line workers would need to be included in the study as the intended recipients. The management layer above front-line workers was also deemed important for dictating the actions and perceptions of the front-line workers due to their direct interactions (Billett, 2004), and therefore were also considered in this thesis. Hence, each organisation was conceptualised as one or two potential activity systems, depending on the variation in the views of front-line and management level workers on the learning objectives of LFI – the deciding factor in the number of activity systems (Nardi, 1996).

The final consideration in the research design was data integration. As can be seen in Figure 6, the data was integrated at several points. Initially the quantitative SNA results were used in selection of interview participants. The results were also used to construct some of the
questions of the interview instrument, detailed below. Using activity theory as a framework for triangulation the results of the thematic analysis and SNA were combined, along with additional information from the interview data, to create a description of the activity systems in each case. Finally, all data sources were triangulated to create a narrative of the enablers and barriers of learning in the LFI process.

4.9.1 Settings and Participants

Organisation recruitment
LFI has been investigated in a number of settings such as aviation (Dillman et al., 2011), healthcare (Nicolini et al., 2011b), and construction (Drupsteen et al., 2013). For this thesis the energy sector was chosen as the context for study for two reasons:

1. More LFI articles focusing on the organisational learning process have been conducted in the energy sector than any other setting (Murphy, Littlejohn, et al., submitted). Conducting the case studies in the energy sector therefore aided with placing the findings of this thesis in the wider body of research given the contextual nature of safety (Perin, 1995).
2. In the past few decades the largest incidents globally have taken place in the energy sector: e.g., the Fukushima Nuclear Accident (2011), the Deepwater Horizon oil spill (2010), and the Chernobyl Disaster (1986). The aim of this thesis is to add to the theoretical knowledge surrounding LFI, and additionally to empower organisations to prevent incidents. As the consequences of incidents in the energy sector can have effects on society and ecosystems that persist over decades (Mousseau & Møller, 2012), it is the energy sector where reducing incidents can have the most benefit to mankind.

Organisations were selected for this thesis through a combination of applying selection criteria and volunteer recruitment. The selection criteria used to recruit organisations were:

- A global energy organisation
- An organisation with a well-established LFI system
- At least 100 workers in the section of the organisation that would take part in the research
- An enthusiastic and committed senior manager to act as a gatekeeper
- A site that has had a major incident in the past 10 year that could have led to the loss of life

Organisations were recruited through a presentation at the Energy Institute’s LFI Users Day. Four organisations volunteered to take part in the study. One, Company X, had less than 100 workers
and so was invited to take part in a pilot study. Company A and Company C met all four criteria and were both petrochemical production sites. Company B had not had a major accident in the last 10 years, however, met all the other criteria. Nonetheless, as Company B was involved in a different side of the energy sector, namely servicing and installing energy equipment in homes, they were included in the study as an interesting point of comparison for Company C.

Participants

[redacted]

Company B was a European gas and electric installation and repair organisation with around 20,000 employees. It was part of a multinational organisation with approximately 30,000 employees world-wide. The largest part of the organization was dedicated to either installing or repairing boilers. The organisation was comprised of regional teams of engineers who spent most of their time driving to customer’s houses and then attending the equipment there. Each team had a supervisor. The team supervisor was considered to be part of the management level of the organization, as they did not usually oversee daily operations and no longer possessed the technical skills to carry out the work of front-line engineers. Teams in general had between 15 and 20 workers. Four teams from Company B were invited to take part in this thesis, two who specialized in service and repair and two who specialized in equipment installation. English was the main language of communication for the organisation. During the collection of the survey data one team underwent personnel changes due to an organizational redistribution of workers. As SNA places relationships at its core, only those team members who were present before and after the change were included in analysis, as they possessed established relationships. This meant that only SNA data from individuals who were in the team both before and after the change were included in the SNA in Chapter 5, and were eligible to take part in the interviews. However, the link to the surveys was also distributed to some of the new team members. Their responses to the LFIQ were included in the analysis in Chapter 7.

Company C was a large European petrochemical production site. English was the mother tongue of most of the workforce at Company C. Globally the organization employed over 10,000 workers. At the site where data were collected for this thesis up to 1,200 were employed. All workers who took part in the research described in this thesis were from the production department. The production workforce was divided into five shifts. In addition to being assigned to shifts, each production team was overseen by a day supervisor, responsible for a sub-section of the overall site. Team supervisors in Company C worked alongside their team members and as
such still possessed technical knowledge. Team supervisors in Company C were therefore considered as front-line employees. Each team supervisor reported to both a shift supervisor, and a day supervisor. Front-line teams ranged from between four and ten members. The managerial workers in production worked from approximately 9:00 to 17:00. Company C had not experienced a major incident for over five years.

Company X was a chemical storage facility whose clients were predominantly energy organisations. The site of the pilot study was a small branch with circa 50 on-site employees. As with Companies B and C, Company X was part of a global organisation with around 80,000 employees. The site had a small management team, with most of the workforce split between two teams. One team was comprised of 11 people, and the other 15 people.

Table 6 shows all the teams who were invited to take part in the thesis and their size. The size of Team Install 2B, the previously mentioned team whose members changed during the research, indicates the number of team members who were present both before and after the organisational change. Over 98% of team members in all three organisations were male.

<table>
<thead>
<tr>
<th>Organisation</th>
<th>Team</th>
<th>Team size</th>
</tr>
</thead>
<tbody>
<tr>
<td>B</td>
<td>Team Repair 1B</td>
<td>14</td>
</tr>
<tr>
<td>B</td>
<td>Team Repair 2B</td>
<td>18</td>
</tr>
<tr>
<td>B</td>
<td>Team Install 1B</td>
<td>19</td>
</tr>
<tr>
<td>B</td>
<td>Team Install 2B</td>
<td>10</td>
</tr>
<tr>
<td>C</td>
<td>Production Management C</td>
<td>4</td>
</tr>
<tr>
<td>C</td>
<td>Shift A Team 1C</td>
<td>9</td>
</tr>
<tr>
<td>C</td>
<td>Shift A Team 2C</td>
<td>5</td>
</tr>
<tr>
<td>C</td>
<td>Shift A Team 3C</td>
<td>10</td>
</tr>
<tr>
<td>C</td>
<td>Shift A Team 4C</td>
<td>7</td>
</tr>
<tr>
<td>C</td>
<td>Shift A Team 5C</td>
<td>7</td>
</tr>
<tr>
<td>C</td>
<td>Shift A Team 6C</td>
<td>8</td>
</tr>
<tr>
<td>C</td>
<td>Shift A Team 7C</td>
<td>8</td>
</tr>
<tr>
<td>C</td>
<td>Shift B Team 1C</td>
<td>9</td>
</tr>
<tr>
<td>C</td>
<td>Shift B Team 2C</td>
<td>4</td>
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<tr>
<td>C</td>
<td>Shift B Team 3C</td>
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<tr>
<td>C</td>
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<tr>
<td>C</td>
<td>Shift B Team 5C</td>
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<tr>
<td>C</td>
<td>Shift B Team 6C</td>
<td>7</td>
</tr>
<tr>
<td>C</td>
<td>Shift B Team 7C</td>
<td>7</td>
</tr>
<tr>
<td></td>
<td>Total</td>
<td>169</td>
</tr>
</tbody>
</table>
The number of participants whose data was used in each analysis approach differed based upon if they had completed the LFIQ, the social network survey, or taken part in an interview. Details of the number of participants in each type of analysis will be provided in Chapters 5, 6, and 7.

4.9.2 Instruments

**Social network quantitative instrument**

The social network survey was a name generator, i.e., a series of questions that required participants to provide names (Borgatti et al., 2018). Quantitative network data could have been gathered either through observation or monitoring of online communication (Knoke & Yang, 2008). Given that previous studies have found access to a computer to be an issue in LFI (Lukic, 2012) I deemed that the use of electronic records as a way of establishing connections would not represent a valid way of creating the social relations matrix. Observation of tasks could potentially have given insight into who was connected to whom, but would neglect any important connections not invited to accomplish a task, such as the health and safety department. I therefore decided to use a name generator survey in this thesis.

It has been noted in literature on SNA that the phrasing of questions can be subjective (Crossley et al., 2015). For example, the strength of relationship that would be required for a participant to indicate that they considered someone as a friend may vary. In line with recommendations by Kvale (2007), to avoid this ambiguity questions in the initial survey were phrased around specific actions, i.e., asking for advice or receiving information. These answers became the initial starting point for later interview questions which would explore the nuances of the responses. As social network surveys are created by researchers, rather than members of the networks under investigation, misunderstanding of terms is a potential validity issue. Several steps were taken to minimise this risk.

Initially I developed the survey with feedback from four representatives of three organisations (the Energy Institute, Company A, and Company X). As these representatives were primarily from managerial positions and the target participants included front-line workers, a small pilot study was undertaken with Company X. Company X provided a supportive role to other energy organisations as a storage facility for both raw products, such as crude oil, and chemicals. The daily tasks carried out by their workers consisted of routine tasks involving hazardous substances, like Company C. In line with recommendations by Rothgeb (2008), I initially presented the survey to a focus group of 10 individuals. I asked the focus group participants to discuss what they understood by each question and made notes. The focus group participants found that the
survey wording was clear, so no further modifications were made at that time. The survey was then distributed to 36 participants at Company X to test the procedure. The response rate of the pilot study was low at 38.9%, which was far lower than the 80% suggested as sufficient for network-level SNA (Hanneman & Riddle, 2005; Wasserman & Faust, 1994). This informed distribution strategies in the actual case studies.

Additional modifications were made to the survey, following feedback received while conducting interviews. Initially the questions on the survey related to receiving information formally had a sub-question inquiring if the information received was useful. Two interview participants, after concluding their interviews, told me that they found this question confusing. Upon reflection I decided that this question should be dropped from the survey as it was discussed as part of the interview. Additionally, ‘useful’ was a very subjective term and could face validity issues during analysis (Crossley et al., 2015). The final version of the survey can be seen in Appendix A.

The final quantitative social network survey consisted of two main questions, each with multiple parts. In line with Knoke and Yang (2008), the first was a closed name generator. A list was provided of all members of the participant’s team. While there are multiple ways of defining a team, in this thesis it was considered to be everyone who reported to the same line manager (Vangrieken, Boon, Dochy, & Kyndt, 2017). As two types of networks were investigated, the formal networks through which participants received incident-information and the informal networks through which participants exchanged information on incidents, a similar approach was employed to Palonen et al. (2004), where the participants were asked two sub-questions: one to establish the formal networks and one to consider the informal. To investigate the informal networks a question from Palonen et al.’s (2004) study was modified, requesting the participant to indicate next to each team member if they would “discuss problems related to safety, e.g. how to safely move heavy equipment from one area of the site to another.” The second sub-question invited participants to indicate next to each team member “who in the past 6 months you have received safety related information from, either through an official communication or at a meeting (e.g. an email announcement from your manager, from a colleague during a safety meeting, a safety alert)”. While network-level analysis requires a definitive boundary to indicate who is included in a network and who is not, key connections often exist outside of formal team designations requiring SNA methods that can capture less defined boundaries (Carolan, 2013). To expand upon the answers provided by the closed name generator and provide insight into the dynamic nature of network boundaries in the LFI process, the second question was an open name
generator in line with methods described by Wasserman and Faust (1994). Participants were able to list people from outside of their team, with a space provided to write the relationship to the participant. Against each person listed, participants were asked the same two sub-questions as the closed name generator.

An additional qualitative question was added to the end of the social network survey asking participants, “please tell us about a recent time when you found safety information useful. How did you use this information to make your work safer? (Did you discuss it with a colleague and have a new idea? Did you take an idea from an accident at a different site and connect it to your work? etc.)”. This question was not necessary for SNA, but prompted participants to think of a situation that could be expanded upon in a subsequent interview. It can be difficult for interview participants to accurately recall experiences (Landen & Hendricks, 1995). Asking participants to think of an example experience while not under any perceived pressures in an interview therefore reduced the number of participants unable to think of an example.

The Learning from Incidents Questionnaire
The LFIQ consisted of 46 questions, each designed to explore how well a particular step in the LFI process was undertaken with regards to one of the five factors identified by Lukic et al. (2012) as relevant to the LFI process (Margaryan et al., 2018). Each question asked participants to rate on a scale of one (strongly disagree) to five (strongly agree) how well a specific element of a process is carried out at their organisation, for example, their organisation listening to ideas and suggestions for improving safety. The questionnaire was validated through analysis of 781 workers from two energy organisations (Littlejohn et al., 2017). The Energy Institute recommends that organisations use the LFIQ to diagnose strengths and weaknesses, recommending that any part of the LFI process that averages below four is in need of attention. As an instrument developed within the energy sector the LFIQ should be a valid instrument within the context of this thesis. [redacted]

Qualitative instruments
The full interview script can be seen in Appendix B. [redacted]. As discussed in Section 4.7, the interviews in this thesis had four requirements:

1. Expand on the quantitative social network data with a qualitative understanding
2. Explore in depth the perceived learning objectives of LFI
3. Describe all aspects of an activity system in detail
4. Provide enough discussion that discursive manifestations of contradictions in the activity system could arise

Initially, three questions were added to the interview protocol to expand upon the quantitative social network data. Two interview questions asked for an explanation of the answers provided by the participant on their social network survey:

- In your survey response you mentioned [answers] as people that you would discuss safety problems with. Why would you discuss safety issues with these people in particular?
- In your answers you also mentioned [answers] as people that you have received information from through formal means. What kinds of information have you received from them?

Where possible, i.e., if the response rate of their team had been sufficiently high, a sociogram was presented to participants. Different positions in the social network were highlighted (such as the most connected actor or an isolated actor) and participants were asked:

- [Present sociogram of team and explain how to interpret it] Where do you think you are on this sociogram and why?

In order to address the second requirement of the interview data, exploration of perceived objectives of LFI, questions inquired about events when learning should have occurred. Prior research has shown that when asked about learning in the workplace, participants tend to describe formal training (Simons & Ruijters, 2004). Thus, participants were asked about different situations that should have involved learning rather than directly about learning. The following questions were added to the interview protocol expanding on the example given in the social network survey asking for “a recent time when you found safety information useful”:

- In the survey you described [information from survey]. Can you tell me more about that?
- Did the information lead you to change your work in any way?
Other questions were asked about the major incident that had occurred in the organisation. As Company B was selected despite not having experienced a major incident in the past decade, this question was modified in interviews with participants from Company B. Instead of describing the incident and asking for subsequent changes, participants were first asked to think of the largest incident that they had heard of in the past 10 years and describe it. They were then asked the same questions as participants in Company C.

- [Describe major incident or ask participant to think of major incident within their company in the past 10 years]. If applicable, how has your job changed as a result of this incident?
- Thinking outside of your own role and experiences, can you tell me what changes you think should have happened in [company] as a result of this incident?

As the last question of the interview participants were also asked what they perceived as the purpose of LFI. This was placed as the last question in order to not affect answers to more descriptive questions that came before it. After the pilot interview it became obvious that most participants would focus on the outcome of the activity system in their response, i.e., reducing the number of incidents, rather than the learning objectives. Two additional questions were therefore added to more specifically explore successful learning:

- What do you think is the purpose of investigating and sharing information about incidents?
- How would a worker change their behaviour if they were learning well from incident-information?
- How can [company] know if their workers are learning well from incident-information?

The third requirement of the interview was that enough details were produced on each element of the LFI activity system in that organisation to be able to create a description. Each of the questions to this point in the script were labelled with the elements of the activity system on which they should produce data. This labelling can be seen in the interview script in Appendix B. After application of these labels it became apparent that there would likely be few details
volunteered by participants on the rules and potentially the tools of the system. One final question was added to address this need:

- How does [company] share information about incidents?

The last requirement of the interview script was that it would produce enough dialogue to allow discursive manifestations of contradictions to emerge. As the interview script consisted of 11 questions and explored the activity system from a variety of angles, I decided that enough data should be collected to allow tensions to manifest.

### 4.9.3 Interview Selection Criteria

A common approach in mixed methods study designs is to collect data sequentially, allowing qualitative methods to build on quantitative results and probe explanations for observed trends (Creswell & Plano-Clark, 2011). In SNA this type of design is well established as the quantitative results are often transformed into a sociogram whose interpretation requires qualitative details of context (Teddlie & Tashakkori, 2009). In this thesis all research questions were exploratory in nature. The interview script was designed to generate a diversity of experiences and opinions in the context of LFI. Maximum variation sampling, in other words, purposefully selecting participants from as diverse situations as possible, was employed (Suri, 2011). This approach to sampling allows detection of ‘shared patterns that cut across cases and derive their significance from having emerged from heterogeneity’ (Patton, 2002, p235).

Two factors were taken into consideration at each of the three organisations when selecting participants for follow-up interviews. The first was job role. Prior research has provided evidence that differences in perspective often appear between management and front-line employees (Nyssen et al., 2018). As managerial roles differ in tasks and routines to those on the front-line, they are likely to have different understandings about LFI-related endeavours (Lukic, 2012; Pea, 1993). Ensuring that both management and front-line perspectives were well represented in the interviews was therefore a priority. Table 7 shows the number of participants from front-line and managerial roles. All participants were male. Due to several invitations being declined to take part in an interview from Company B management, it was not possible to represent the management viewpoint in as much depth as in Company C.
Table 7 Summary of interview participants

<table>
<thead>
<tr>
<th>Company</th>
<th>Job type</th>
<th>Number of participants</th>
</tr>
</thead>
<tbody>
<tr>
<td>B</td>
<td>Engineering front-line</td>
<td>9</td>
</tr>
<tr>
<td>B</td>
<td>Engineering management</td>
<td>2</td>
</tr>
<tr>
<td>C</td>
<td>Production front-line</td>
<td>10</td>
</tr>
<tr>
<td>C</td>
<td>Production management</td>
<td>6</td>
</tr>
<tr>
<td>Total</td>
<td>Front-line</td>
<td>27</td>
</tr>
<tr>
<td>Total</td>
<td>Management</td>
<td>18</td>
</tr>
<tr>
<td>Total</td>
<td>All</td>
<td>45</td>
</tr>
</tbody>
</table>

In addition to job role, participants’ positions on the sociograms produced for each team were taken into consideration, in line with Rienties et al. (2015a). Participants were chosen as they were 1) a bridge builder, i.e., the actor most frequently chosen by their colleagues (Rienties, Johan, & Jindal-Snape, 2015b); 2) an actor who selected the bridge builder; 3) an isolate, i.e., an actor with few connections (Knoke & Yang, 2008); or 4) an actor who did not select their manager. It was unusual in all three organisations that a participant did not say they would seek advice and receive information formally from their manager. Hence this was used as a selection criterion. The job role and social network position criteria were given equal weighting in terms of importance of gathering diverse views; however, as participation in interviews was voluntary a secondary consideration was availability. In Company C teams were densely connected, so availability of team members became a practical reason to select participants. This was done on the rational that there were a high number of structurally equivalent actors, as most were connected to all other team members (Hanneman & Riddle, 2005). In Company B availability was also sometimes an issue for the requested participant. When a particular individual was unavailable to take part in an interview, I requested a replacement who occupied the same social network position and job role. In some teams it was not possible to select an isolate or a participant who did not choose their manager. In these cases, an additional team member was invited to take part in the interview to ensure at least four team members were invited to participate. This additional team member’s selection was based on availability.

4.9.4 Procedure

In Company C my initial step in conducting the research was to visit the site of data collection. During these visits I was able to better understand the context of the organisations and meet with various workers, such as shift supervisors or a member of the health and safety department. In Company B it was not possible to visit the site, as the teams who would take part in the study did
not work at a single location. However, I did have meetings with a variety of employees, such as the director of health and safety, in Company B on Skype before commencing data collection.

Surveys were sent to several teams at Companies B and C. The surveys were created using JISC Online Surveys. Participants initially received the link to the survey from a gatekeeper at their organisation. If they did not complete the survey, I sent each participant up to three reminder emails. As names were gathered from participants when they completed the survey in order to allow for SNA, it was possible to target only participants who had not completed the surveys. [redacted]

Interviews were then conducted with participants selected to represent a wide-range of views, either based on their job role or social network position. In order not to influence my conduct during the interviews, no analysis related to activity theory was carried out between the distribution of the surveys and the interviews. The SNA and thematic analysis described in Chapters 5 and 6 were conducted before any specific steps related to activity theory were carried out. This allowed me to become as familiar as possible with the various aspects of the LFI process in each organisation, before creating a holistic model using activity theory. Analysis of the LFIQ data was only conducted after activity theory-based analysis was complete. This prevented the results of the LFIQ influencing my analysis as I created activity system descriptions and coded discursive manifestations of contradictions.

All interviews were recorded using a voice recorder. The interview recording was transferred from the recording device to the Open University’s internal storage infrastructure as soon as possible, and deleted from the portable recording devices. I transcribed all 45 interviews. This process resulted in 495 pages of transcript containing a total of 261,991 words. During the interview process and analysis I made notes. All transcripts were imported into NVivo Plus version 11 for analysis in line with recommendations by Woolf and Silver (2018).

4.9.5 Quantitative Analysis Approaches
Quantitative analysis techniques were used with the data produced from the social network survey and the LFIQ. Network statistics were calculated for teams with over a 60% response rate. This is lower than the recommended rate of 80% (Hanneman & Riddle, 2005), however, follow-up interviews reduced the chance that an interesting structural feature was missing due to missing data, the primary reason for the high requirement. Ego-level statistics were calculated for all participants who responded to the social network survey or took part in an interview. Details of the network-level and ego-level statistics calculated are presented in Chapter 5. Standard...
statistical measures such as mean and standard deviation were calculated using the data of the LFIQ.

4.9.6 Qualitative Analysis Approaches

Several qualitative analytical approaches were employed in this thesis to analyse the qualitative data generated by the interviews. For RQ1 a description of different ways that participants had used networks was required. As this required the summarisation of the experiences of a group a systematic text condensation approach was used (Malterud, 2012). Systematic text condensation is a based on phenomenology and is therefore concerned with how a group experience a particular phenomenon (Creswell & Poth, 2013). For example, Jangland, Nyberg, and Yngman-Uhl (2017) examined perceptions of dangers to patients’ safety in Swedish hospitals. While other qualitative analysis approaches, such as content analysis, thematic analysis or emergent themes analysis, could have been employed in this research, I felt systematic text condensation was more aligned to the research question; the goal of this qualitative investigation was to understand the concrete experiences that participants have had as part of networks. It is therefore a research question that aims to describe rather than identify inter-connected themes, or compare relative abundance of experiences. Systematic text condensation is a method centred on describing the perspectives of a group and was therefore the most suitable approach.

The interview data was also analysed using thematic analysis to explore what participants perceived as the learning objectives of LFI. Thematic analysis is suitable for identifying patterns and themes within a set of data: generating themes across data rather than creating a summary of experiences as in phenomenological approaches (Braun, Clarke, Hayfield, & Terry, 2019). Unlike content analysis, thematic analysis does not assign value to the number of times a theme or one of its sub-codes is applied to the data (Braun & Clarke, 2006; Hsieh & Shannon, 2005). As the questions in the interview script gave little guidance on the types of events that participants should provide in order to maximise diversity of answers, no meaning could be ascribed to the number of times certain themes were applied (Gubrium & Holstein, 2002). Thematic analysis was therefore selected as the most appropriate analytical tool to address RQ2.

Finally, two qualitative approaches were undertaken to answer RQ3a and RQ3b. Activity theory requires a description of the elements of the activity system to be produced (Shanahan, 2010). Systematic text condensation was therefore once again applied to produce descriptions of the rules and tools of the activity systems of each organisation (Malterud, 2012). The results of both the qualitative and quantitative SNA were used to create a description of the division of
labour and community elements of the systems. Likewise, the results of the thematic analysis were used to create a description of the objectives of the activity system.

Discursive analysis of manifestations of contradictions was conducted to identify tensions in the dialogue of participants (Postholm, 2015). Themes across these types of discursive tensions were noted to identify overarching contradictions in the activity systems. As shall be described in Section 7.2.4, traditional techniques that have been used in activity theory to conduct this type of analysis were found to miss key narratives in the data. An approach using ‘versus coding’ was therefore adopted to identify contradictions. Versus coding involves applying codes to data that identify two entities in tension (Saldaña, 2016). While novel within activity theory, versus coding has been used in approaches such as action research to make hidden tensions visible and explicit (Altrichter, Posch, & Somekh, 1993; Wolcott, 2003).

4.9.7 Validity and Reliability

Yin (2013) describes three types of validity that should be considered: construct, internal, and external. Internal validity describes the strength of the logical arguments of the design to justify any conclusions drawn (Gibbert, Ruigrok, & Wicki, 2008). For example, the research design should be based on a strong theoretical framework, to which results are compared (Yin, 2013). Internal validity was considered in this thesis in two ways. Firstly, a systematic literature review was conducted to gain an overview of the current research in LFI (see Chapter 2 and Murphy, Littlejohn, et al., submitted). Secondly, the research design was built upon an explicit theoretical framework (see Chapter 3). This allowed the results to be considered within this framework.

Construct validity refers to whether a method represents an adequate operationalisation of a concept (Modell, 2005). Data triangulation is one way to address this, as multiple methods presenting a similar perspective increase the likelihood that this perspective is close to reality (Twining et al., 2017). Presenting results back to the population in which the data was gather can also increase construct validity (Yin, 2013). In this thesis data was integrated and triangulated at various points through the research process (see Figure 6). The use of activity theory as a heuristic for triangulation aided this process. In addition, the results of the study were presented at various industrial conferences (see Murphy et al., 2018b; Murphy, Littlejohn, Rienties, King, & Bryden, 2018a) and in presentations back to participants. Furthermore, the results of RQ2 were translated into a workshop. Participants from Company C, as well as another organisation not involved in this thesis found the taxonomy of learning objectives produced in response RQ2 to be useful and have meaning (mean rating of 4.33 out of 5.00 from 63 participants). Finally, the construct validity
of the sociograms produced through quantitative SNA was assessed when presented back to participants as part of the qualitative follow-up interviews.

External validity deals with the generalisability of results (Gibbert et al., 2008). While case studies do not often lend themselves to statistical generalisability, i.e., where a result is generalised to a population, they can have analytical generalisability, i.e., when a result can be generalised via integration into theory (Flyvbjerg, 2006). The use of multiple cases and a clear rationale for selection of cases are both important for external validity (Yin, 2013). In this research multiple cases were used. [redacted] The context of Company B was different and provided a reference for how applicable across the sector findings may be. In addition, as mentioned above, the workshop on learning objectives was conducted with an energy organisation who did not take part in this thesis, who found the findings of RQ2 useful and relevant for their own organisation. Furthermore, clear selection criteria were used when selecting the cases to clarify potentially similar organisations to those in this thesis.

Reliability, on the other hand, is concerned with repeatability, i.e., would a different researcher with the same data come to the same conclusion (Gibbert et al., 2008). The inclusion of multiple people in the research process is desirable for this reason (Twining et al., 2017). Reliability in this thesis was addressed in two ways. [redacted] This was then applied to the data of Company C to compare how well the data fit a new set of data. The coding scheme was then updated and applied to the data of Company B. This was a form in intra-rater reliability, with the application of codes to new data allowing reflection on the suitability of the coding scheme. Secondly, the findings of the thematic analysis were presented to two other researchers. For the thematic analysis each researcher coded two transcripts with the coding scheme. Disagreements were resolved through discussion and the coding scheme updated to reflect the differences. [redacted]. For the discursive manifestations of contradictions relevant quotations for each contradiction were presented to two other researchers. The nature of the contradiction indicated by the quotations was discussed until all parties agreed. For the phenomenological analysis key quotations were presented next to the created summary to two additional researchers. These researchers provided thoughts on whether the summary was an accurate representation of what was described in the quotations. The summary was updated accordingly.
4.10 Ethics

Ethical approval was for the study was obtained from the Open University Human Research Ethics Committee: HREC/2017/2510/Murphy. A memorandum communicating the approval can be seen in Appendix C.

Due to the potentially sensitive nature of discussing incidents confidentiality of participants was a prime concern. This was particularly relevant given that network-level SNA was employed, where the names of participants must be collected in order to create sociograms. After the initial creation of sociograms and subsequent selection of interview participants, all data was anonymised. Interview data was immediately removed from recording devices following interviews and stored in the Open University One Drive server. As far as possible this thesis has maintained the anonymity of participants. For example, in Chapter 5, despite the sociogram position being used to select participants, this position was not linked to qualitative quotations to maintain the anonymity of participants.

In addition to protecting the identity of participants, careful consideration has been given to the amount of detail provided on each organisation that took part in this research. I had to sign non-disclosure agreements with two of the organisations in order to protect their identity. Representatives from both organisations have therefore looked over this thesis to ensure that the identity of all organisations is protected.

Finally, it should be noted that SNA has specific ethical issues when used in organisations. Kadushin (2005) raised the concern of benefits to the participants of research in studies using SNA: academics and organisations usually benefit from SNA approaches, but do individual participants? I would argue that in this case, due to the nature of the topic, there were clear benefits for participants, who will hopefully work in a safer environment through the practical use of the findings of this research. Moreover, several specific concerns were raised by participants that are discussed in the Chapter 7 exploring barriers to learning. This thesis was a safe way for that feedback to be heard by those who have the power to make changes, without risking negative consequences for the participants.

Besides consideration of benefits to the participants, the interview technique used in this thesis of presenting the sociogram to participants and asking them to identify themselves raised an interesting dilemma: should participants be told if they were correct or not. I chose not to reveal the position of the participant until the end of the interview in order to not influence any of their responses. In one case I chose to withhold the information about the position of the participant, as they felt they occupied a central position in the network, whereas I had chosen
them for participation because they were an isolate. All other participants had a clear understanding of where they were in the sociograms.

Finally, an ethical concern arose over the hierarchical pressure on participants to complete the survey which had been sent to them by their manager. As discussed above, the quantitative instruments were sent to participants via a gatekeeper, who usually forwarded the links on to team supervisors. This was due to the low response rate in Company X during the pilot study. Many managers chose to help increase the response rate by setting aside 30 minutes in a team meeting to complete the surveys. This could be seen as coercing participants into completing surveys as they did not want to disobey their manager. Nevertheless, I decided that as the manager could not check if their team members had submitted their responses, a participant could have refused if they chose. In the survey design I made checking the consent box a mandatory field, but if I was to repeat the research, I would not do this. This would allow participants to opt out of contributing their data in situations where they had been instructed to complete the survey by their manager.

4.11 Researcher Positionality
As this research is primarily qualitative, with the incorporation of quantitative data to complement the qualitative, it is important to be clear about my positionality as a researcher. While, as outlined above, every effort was made to incorporate the opinions and perspectives of others to increase validity and reliability, the majority of analysis was undertaken solely by myself and my positionality will therefore have inevitably influenced the interpretation of the data (Bourke, 2014).

I am a 34-year-old British female. In addition, I have spent around a decade abroad, working in Singapore and Japan, and then studying in Finland. My first degree was a master’s in engineering, however since that time my world has revolved around education. In Japan I was an English teacher in primary and secondary schools for four years. I then spent two years working in a tech giant in Singapore for the learning and development team. The role required me to think about the educational systems in place in the organisation and to make them more efficient. After that I moved to Finland and lived there for three years while getting my master’s in education and during the start of my PhD.

Through my work in Japanese schools I grew to understand the importance of pedagogy. In primary schools I usually led the classes I taught, however in secondary schools I was an assistant to a Japanese teacher of English. I was privileged enough to work with 20 teachers, many
of whom had different approaches to teaching and pedagogy. Especially in the later years of secondary school I saw that memorisation of vocabulary and grammar was not enough to enable students to use English; students needed to practice English in scaffolded conversations.

Through my work in Singapore I came to appreciate learning from a very different perspective, combining the systematic mindset of engineering with the consideration of how an individual would engage with training materials. My role was to automate or reduce the workload of class facilitators, ensuring as consistent an experience across the global organisation as possible. I also facilitated a lot of internal classes within the company, noticing that adults learn in a different manner to children. Adults all came with their own experiences and could often add their own insights on topics.

This view on the importance of dialogue and discussion was further cemented when studying in Finland. The Finnish education system is one that emphasises collaborative work, being heavily influenced by socio-cultural traditions. The implementation of these theories could often be seen in the design of my classes. My master’s programme was very international, with representatives from 15 countries. Many classes were set-up to provide some kind of stimulus, either a question or a journal article, which would then be discussed, bringing in as many experiences from the education systems of my classmates and I as possible. All these experiences have influenced my conceptualisation of learning, and in particular what I consider to be effective ways to support learning.

Despite my engineering background I entered into this project with relatively little knowledge of the world of health and safety. While working towards my engineering degree, my classmates and I had often been inclined to skip classes on health and safety as, compared the mathematics that featured heavily in other subjects, it seemed like common sense. However, having an engineering degree was beneficial in two ways in this thesis. Firstly, while some of the technical details were lost on me, I think it aided me in communicating with participants who were also from engineering backgrounds. Secondly, I noticed that having an engineering degree gave me a social currency with gatekeepers. Gatekeepers seemed to respect the fact that I had what was perceived as a difficult degree to obtain.

Another element of my positionality that influenced this thesis was my gender. All participants whom I interviewed were male and often older than I was. Particularly as some of the topics discussed were of a sensitive nature, I think participants were unconsciously more comfortable being open and vulnerable than they perhaps would have been with a male interviewer (Manderson, Bennett, & Andajani-Sutjahjo, 2006). My gender may have also had a
different effect in some interviews, as perhaps most aptly shown by one participant inviting me to have dinner with him after the interview.

The final piece of my positionality that should be reflected upon here is my training in counselling. During my time in Japan I was a peer counsellor for other English teachers. Furthermore, my Master of Education included a specialisation in guidance and counselling. All my training focused on the humanistic approach to counselling inspired by Rogers (1957). This style of counselling focuses on active listening, summarising, and rephrasing comments to encourage the client to find their own solutions to issues. This training had a definite influence on my interview style, as I often rephrased the comments of participants to ensure that I understood what they meant and to encourage them to expand on their answers. As outlined by Kvale (2007) this can actually be beneficial in analysis, as participants have confirmed that you understood what they said in the intended manner.

4.12 Summary
Chapter 4 discussed ontological and epistemological considerations in relation to LFI and the research questions in this thesis. Considerations of mixed methods, case studies, and the methods used in the research design of this thesis were then presented. These were then summarised with consideration to the theoretical frameworks contained in Chapter 3. The chapter ended with a detailed description of the research design, including aspects that will be common across the three analytical chapters, such as organisational context. Further details of analysis are presented when relevant in Chapters 5 – 7. Chapter 5 will discuss the first part of the research design outlined in this chapter, mixed methods SNA, in order to address RQ1.

5 Networks in Learning from Incidents
Chapter 5 details the first stages of the case study analysis, which addressed RQ1: how are networks used in LFI?

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4 A section of the analysis discussed in this chapter was published in the following:
A comprehensive justification for this research question can be found in Section 2.3.1. Additionally, rationale behind methodological choices was given in Chapter 4. Figure 7 shows how the analysis presented in this chapter fits into the broader design of the thesis.

Figure 7 Analysis covered in Chapter 5

5.1 Introduction

The learning from incidents (LFI) process has been conceptualised as a series of steps that involve incidents being reported and analysed, followed by the construction of summaries which are distributed around an organisation for others to learn vicariously (Drupsteen et al., 2013; Margaryan et al., 2018). Research to date has focused on how incidents are reported (e.g., Armitage et al., 2010), investigated (e.g., Nicolini et al., 2011a), or the kinds of recommendations produced by the LFI process (e.g., Stackhouse & Stewart, 2017). However, reviews on LFI have highlighted that how information on incidents is communicated, a vital step in enabling others to
learn from the experiences of others, is currently a gap in the literature (Drupsteen & Guldenmund, 2014; Lindberg et al., 2010).

The majority of organisations have a formal procedure through which incident alerts or reports are disseminated, such as making entries into databases (Jacobsson et al., 2011). The few studies that have examined the dissemination of incident-information have tended to focus on the contents of these databases, and the quality of information contained within (J. G. Anderson et al., 2010; Jacobsson et al., 2010). Additionally, communication strategies, such as meetings and emails, have been noted by research into organisations’ LFI processes (e.g., Lukic, 2012; Reiter-Palmon et al., 2015), although unpacking the nuances of different formal communication strategies after an incident investigation has yet to be the driving force of any study.

Formal communication strategies in the LFI process are complemented by so called ‘informal networks’ that supplement incident-information-exchange. In their study of a Norwegian energy organisation and its contractors, Gressgård and Hansen (2015) postulated that contractors could aid in incident-information dissemination, as they work in close contact with a variety of teams across an organisation. Their results found a significant link between the strength of relationships between workers and contractors, knowledge-exchange, and perceived effectiveness of the LFI process. The study represented an important initial step in establishing the importance of informal network connections. Nevertheless, understanding how these informal networks supplemented formal information-exchange was beyond the scope of Gressgård and Hansen’s (2015) study.

Prior research outside of the context of LFI has demonstrated that networks can have various functions beyond the exchange of information, such as tacitly influencing organisational practices (Nonaka & Takeuchi, 1995). Furthermore, the structure of networks and types of connections that exists within and between teams has been shown to be of great importance in professional settings (Hakkarainen et al., 2004). For example, Daly and Finnigan (2011) explored the way that strong and weak ties changed during departmental reforms in school leaders, allowing leaders to exchange knowledge and innovate. Extending this perspective to LFI, there is a need to understand the role of both formal and informal networks during the LFI process.

As information dissemination has been established as a key part of the LFI process (Margaryan et al., 2018), a mixed methods social network approach was adopted in Chapter 5. The quantitative constituents of the approach effectively mapped the formal and informal flows of information on incidents in three organisations. These methods were in-line with those employed by L. Zhang, He, and Zhou (2012) to explore similar network related questions.
However, as the functions of networks in the LFI process remains relatively unexplored, consistent with Mittelmeier et al. (2018), follow-up qualitative methods were employed to triangulate and build on the quantitative social network results. This qualitative portion explored the ways in which both formal and informal networks were used by workers in different positions.

5.2 Methods

5.2.1 Settings and Participants

Data were collected across sites at three organisations. Descriptions of the context of each organisation, in addition to the way in which teams were recruited to take part in the study, can be found in Section 4.9. Collection of the social network data was the first step for each organisation (see Figure 6 in section 4.9 for the timeline of each step taken in data collection and analysis). Initially data were collected through distribution of social network surveys. In line with maximum variation sampling (Suri, 2011), participants for qualitative follow-up interviews were selected to encourage maximum diversity in their answers. Participants for follow-up interviews were recruited from different social network positions, calculated from the survey data, and a diversity of formal roles.

[redacted]

Table 8 Response rate to survey by team and organisation

<table>
<thead>
<tr>
<th>Company</th>
<th>Team</th>
<th>Team size</th>
<th>Responses received</th>
<th>Response rate</th>
<th>Included in network-level analysis</th>
</tr>
</thead>
<tbody>
<tr>
<td>B</td>
<td>Team Repair 1B</td>
<td>14</td>
<td>9</td>
<td>64.3%</td>
<td>Yes</td>
</tr>
<tr>
<td>B</td>
<td>Team Repair 2B</td>
<td>18</td>
<td>12</td>
<td>66.7%</td>
<td>Yes</td>
</tr>
<tr>
<td>B</td>
<td>Team Install 1B</td>
<td>19</td>
<td>16</td>
<td>84.2%</td>
<td>Yes</td>
</tr>
<tr>
<td>B</td>
<td>Team Install 2B</td>
<td>10</td>
<td>7</td>
<td>70.0%</td>
<td>Yes</td>
</tr>
<tr>
<td>C</td>
<td>Production Management</td>
<td>4</td>
<td>4</td>
<td>100.0%</td>
<td>Yes</td>
</tr>
<tr>
<td>C</td>
<td>Shift A Team 1C</td>
<td>9</td>
<td>7</td>
<td>77.8%</td>
<td>Yes</td>
</tr>
<tr>
<td>C</td>
<td>Shift A Team 2C</td>
<td>5</td>
<td>5</td>
<td>100.0%</td>
<td>Yes</td>
</tr>
<tr>
<td>C</td>
<td>Shift A Team 3C</td>
<td>10</td>
<td>6</td>
<td>60.0%</td>
<td>Yes</td>
</tr>
<tr>
<td>C</td>
<td>Shift A Team 4C</td>
<td>7</td>
<td>5</td>
<td>71.4%</td>
<td>Yes</td>
</tr>
<tr>
<td>C</td>
<td>Shift A Team 5C</td>
<td>7</td>
<td>5</td>
<td>71.4%</td>
<td>Yes</td>
</tr>
<tr>
<td>C</td>
<td>Shift A Team 6C</td>
<td>8</td>
<td>8</td>
<td>100.0%</td>
<td>Yes</td>
</tr>
<tr>
<td>C</td>
<td>Shift A Team 7C</td>
<td>8</td>
<td>7</td>
<td>87.5%</td>
<td>Yes</td>
</tr>
<tr>
<td>C</td>
<td>Shift B Team 1C</td>
<td>9</td>
<td>9</td>
<td>100.0%</td>
<td>Yes</td>
</tr>
<tr>
<td>C</td>
<td>Shift B Team 2C</td>
<td>4</td>
<td>4</td>
<td>100.0%</td>
<td>Yes</td>
</tr>
<tr>
<td>C</td>
<td>Shift B Team 3C</td>
<td>9</td>
<td>9</td>
<td>100.0%</td>
<td>Yes</td>
</tr>
</tbody>
</table>
Participants from Company B came from four teams of engineers (n = 61). As the teams worked independently over a large geographical area, there was no overarching managerial unit. Instead, each team had one supervisor. The fourth team of engineers underwent personnel changes during the middle of receiving responses to the survey. As SNA focuses on relationships, only those participants who were members of the team both before and after the change were included in this thesis. The teams were split between job function to maximise diversity of opinions in the follow-up qualitative interviews: two teams that were responsible for installing equipment, and two that repaired equipment. 60 of the participants from Company B were male, and one was female. 11 participants from Company B took part in follow-up interviews, as described in Table 9, all of whom were male.

Two shifts of a department focused on production took part in the study from Company C. Seven teams from each shift were invited to complete the initial survey (n = 104). In addition, four participants from the production management team, who were responsible for the day to day operations of all teams, were invited to complete the survey. 103 participants were male, and one was female. Of these participants 12 took part in follow-up interviews, as described in Table 9, all of whom were male. Four additional interviews were held with those in managerial positions.
to obtain a wider range of views from the managerial standpoint, meaning 16 interviews were conducted with employees from Company C in total.

In summary, across the three organisations there were a total of 232 workers who were invited to complete social network surveys. Of this 162 chose to participate and complete the surveys, a 69.8% response rate. In addition, 45 interviews were conducted to further explore the perceptions of the participants’ networks.

5.2.2 Qualitative Selection Criteria
Two factors were taken into consideration at each of the three organisations when selecting participants for follow-up interviews. The first was job role. As managerial roles differ in tasks and routines to those on the front-line, they are likely to have different understandings about LFI-related endeavours (Lukic, 2012; Pea, 1993). Ensuring that both management and front-line perspectives were well represented in the interviews was therefore a priority. Table 9 shows the number of participants from front-line and managerial roles.

In addition to job role, participants’ positions on the sociograms produced for each team were taken into consideration, in line with Rienties et al. (2015a). Participants were chosen as they were 1) a bridge builder, i.e., the actor most frequently chosen by their colleagues (Rienties et al., 2015b); 2) an actor who selected the bridge builder; 3) an isolate, i.e., an actor with few connections (Knoke & Yang, 2008); or 4) an actor who did not select their manager. It was unusual in all three organisations that a participant did not say they would seek advice and receive information formally from their manager. Hence this was used as a selection criterion.

5.2.3 Instruments
The quantitative instrument of the study was described in depth in Section 4.9. It consisted of questions that asked participants who in their team they would ask for advice on a safety related issue, and who they had received safety information from in the past six months. A second set of questions asked similar questions, but instead of asking participants to indicate people in their team, the participant was requested to list people from outside of their team who they would ask for advice or from whom they had received information.

The creation of the qualitative interview script was discussed in Section 4.9 and can be seen in full in Appendix 2. Three interview questions were designed to probe participants to expand upon the results of the network surveys, building upon the descriptions obtained via the
quantitative data to understand why networks were structured in a certain way. The first question reminded participants who they had indicated as members of their team that they would go to for advice, and then requested details of why. If the participant had listed additional people in their survey response from outside their team, they would then be asked about these as well. The second question reminded participants who they had said they received information from formally, from both inside and outside their team. I asked what kinds of information they received from these people. Follow-up prompts focused on asking how this information was used, and if they found it useful. 13 participants who had not responded to the initial quantitative social network survey were interviewed due to their position in the social network, such as being an isolate, or because they were a manager. In these cases, the respondent was initially asked who they would approach for advice on safety related issues, and who they had received information from on safety related issues in the past six months. Subsequent questions were as above.

For the final network question, participants were presented with a sociogram of their team, in line with recommendations by Molina, Maya-Jariego, and McCarty (2014). Each team member was indicated by a square in the diagram, and the size of the square was proportional to the in-degree of that team member, i.e., how many people had chosen that individual. Different social network positions were highlighted, e.g., a bridge builder or an isolate. The participant was asked if they could identify their position in the diagram and describe why they chose that position. For some participants it was not possible to draw a sociogram of their team, due to a low team response rate. In interviews with these participants the question regarding sociograms was not asked.

5.2.4 Quantitative Analysis

The data was analysed from both a network- and an ego-level perspective. A response rate of 80% is recommended for conducting network-level analysis (Hanneman & Riddle, 2005). The 80% response rate is due to the danger of interesting structural network features, such as cliques or so-called ‘structural holes’ (discussed in Section 3.2.2), remaining undiscovered (Borgatti et al., 2018; Burt, 2004). The inclusion of a variety of network positions, including isolates and those who did not select their manager, in the qualitative selection procedure minimised the risk of interesting structural features being undiscovered due to missing data. Hence the required response rate for teams to be included in the network-level quantitative analysis was reduced to 60%. Network-level analysis thus was conducted only on [redacted]. In Company B sociograms were created for all four teams, whose response rates were all over 60%. In Company C network-level analysis was
conducted all teams except Shift B Team 5C and Shift B Team 7C, as their response rate was under 60%. Table 8 includes details of the response rate and whether a team was included in the network-level analysis.

A sociogram of each team was drawn using the Netdraw software package. Sociograms for both informal advice-seeking networks, and formal information-receiving networks were created. If data was missing, i.e., the answers from non-responders, the responses of others were not mirrored. Organisations are hierarchical structures, both formally and informally, and there are usually people based on formal positions and social power who are more central than others (Venkataramani et al., 2016). If responses were mirrored, then a junior member of the team, who would seek advice from everybody but would be one of the last approached by others for advice, could have their in-degree artificially inflated through mirroring responses. The sociograms therefore represented the minimum connectedness of the team. UCINET was used to calculate the network densities of all teams. The density of a network is a measure of the proportion of edges that are present, compared to the theoretical maximum. If everyone indicated that they would discuss issues with everyone else in the team, then the density would be 1.00. If everybody chose half of the team members as people that they would feel comfortable discussing issues with, then the density would be around 0.50.

Data was examined for all participants as an ego, i.e., a single person, without necessarily drawing upon their whole team’s data. Unlike network-level analysis, ego-level analysis could be conducted regardless of the overall response rate of a participant’s team. Various descriptive statistics of each ego were calculated relating to either the size of their network, or the diversity of their relationships. The size of the network was represented using the out-degree, i.e., the number of people the respondent chose. The size of a person’s network is a simple measure, but has been shown to correlate with a wide variety of variables (Crossley et al., 2015). Theoretically the more connections to alters, i.e., other people, that an individual possesses, the more opportunities exist for that individual to access resources and information (Burt, 2004). However, more connections require more time to manage, which can offset the advantages provided by greater access to resources (Hakkarainen et al., 2004). One limitation of the in-degree and out-degree is that the data was being aggregated from teams of different sizes, so the maximum number of internal ties would vary from team to team.

The diversity of an ego’s relationships, following the examples set by other SNA studies, was measured using two statistics: the external-internal index (EI-index) (Rienties et al., 2015a; Rienties & Tempelaar, 2018) and Agresti’s index of qualitative variation (IQV) (Halgin & Borgatti, 2012; Lumino, Ragozini, van Duijn, & Vitale, 2017). The EI-index is a ratio of the number of
connections within a person’s team compared to the number of connections external to that team. It can be expressed as shown in Equation 1. The EI-index ranges from -1, when an ego’s connections are only within their team, to 1, when an ego’s connections are only external. The IQV is similar but requires a researcher to categorise each connection.

After reading through all connections from all three organisations I inductively generated the following four categories for this analysis: internal, health and safety specialist, contractor, external colleague (Strauss & Corbin, 1998). These categories were generated inductively, however similar categories have been used in other studies in the LFI context. For example, both Drach-Zahavy et al. (2014) and Nicolini et al. (2011b) differentiated between different groups of healthcare practitioners and health and safety professionals, and Tamuz et al. (2011) explored interactions between colleagues from the same organisation but different departments, in other words external colleagues. Gressgård and Hansen (2015) split their participants into contractors and non-contractor groups. The equation for calculating the IQV can be found in Equation 2. Each \( P_i \) represents the proportion of ties that fell into a category, such as health and safety specialists, and \( r \) represents the total number of categories. An IQV value can range from 0, where all connections are from the same category, to 1, where all connections are from different categories.

\[
EI\text{-index} = \frac{n_{\text{external}} - n_{\text{internal}}}{n_{\text{total}}}
\]

*Equation 1 External-intertnal index formula*

\[
IQV = \frac{r(1 - P_1^2 - P_2^2 \ldots - P_r^2)}{r - 1}
\]

*Equation 2 Agresti’s index of qualitative variation formula*

### 5.2.5 Qualitative Analysis

In line with RQ1, the qualitative data related to the different ways in which networks are used during the LFI process. A systematic text condensation approach was therefore used to summarise the different usages of networks mentioned by participants, as outlined by Malterud (2012).
Through the survey and interview questions broad descriptions were generated of how the formal and informal networks were experienced by each participant, the first step in phenomenal analysis approaches (Giorgi et al., 2017). While only three of the interview questions were specifically written with the intention of generating discussion on networks, I considered answers to all questions of the interview as potentially relevant. Despite other questions not being specifically designed to elicit answers on networks and communication of incident-information, aspects of the exchange of incident-information were often interwoven in responses to other questions. As outlined by Gubrium and Holstein (2002), while semi-structured interviews have initial questions to prompt responses on particular topics, their flexible nature means that relevant comments may be made at any time during the interview, as participants may recall additional details at any time, or veer away from the intended structure of the interview. I initially transcribed all interviews and then read through each transcript, before inductively identifying four network-use related themes: information dissemination, information gathering, contextualising, and sharing (Strauss & Corbin, 1998). An overview of these themes is presented in Table 10.

<table>
<thead>
<tr>
<th>Theme</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Information dissemination</td>
<td>The formal process through which incident-information is disseminated across an organisation</td>
</tr>
<tr>
<td>Information gathering</td>
<td>Purposefully gathering information on incidents in addition to that received in incident alerts</td>
</tr>
<tr>
<td>Sharing</td>
<td>Exchanging information, best practices, or opinions in either formal or informal settings without the specific intention of discussing incidents</td>
</tr>
<tr>
<td>Contextualising</td>
<td>Understanding the relevance of incident-information to processes</td>
</tr>
</tbody>
</table>

In line with the steps suggested by Malterud (2012), meaning units were then identified. I labelled any length of text that contained information relevant to the role of networks as a meaning unit. At least one of the four identified themes was applied as a code to each meaning unit. The meaning units relevant to each theme were then collated and used to create a description of each code in each organisation. This was achieved through taking two meaning units, and then combining them into a condensate. Each meaning unit was then subsequently added to the evolving condensate. If a meaning unit appeared to refer to a different aspect of the
theme, and thus did not fit with an existing condensate, a new condensate about that aspect was created. Finally, all condensates related to a theme were synthesised into a description.

5.3 Results

5.3.1 Quantitative Findings

Company A
[redacted]

Company B
Figures 14 to 21 show the sociograms of the networks for each of the teams in Company B. The advice-seeking networks were denser than the information-receiving networks. [redacted] Table 11 shows the density of each of the networks for Company B. [redacted] In the advice-seeking networks of all four teams, some members of the team were clearly favoured over others. [redacted] formal positions appeared to play an important role in who actors would contact for advice. Particularly in Teams Repair 1B, Repair 2B, and Install 1B, the team supervisor was a central person in the advice network.

[redacted] In Teams Install 1B and 2B there were some other members of the team who appeared to provide others with formal information on safety besides the team supervisor. Teams Install 1B and 2B had formal positions within their teams at the time called ‘coaches’. It was these coaches who tended to be chosen in addition to team supervisors. The repair-oriented teams no longer had similar formal positions after organisational changes.
Participants are labelled with a code such as APF1.7
A/B/C = Company A / B / C 1st number = team number (1 in example above)
P/E = Production / Engineering 2nd number = individual identifier
F/M = Front-line / Management

Arrows point from a participant to the team members that they indicated in their network survey responses. The size of each participant is proportional to the number of people who chose them in the network survey.

Figure 8 Sociogram of Team Repair 1B’s information-receiving network in Company B
Participants are labelled with a code such as APF1_7
A/B/C = Company A / B / C  1st number = team number (1 in example above)
P/E = Production / Engineering  2nd number = individual identifier
F/M = Front-line / Management

Arrows point from a participant to the team members that they indicated in their network survey responses.
The size of each participant is proportional to the number of people who chose them in the network survey.

Figure 9 Sociogram of Team Repair 1B’s advice-seeking network in Company B
Participants are labelled with a code such as APF1_7
A/B/C = Company A / B / C          1st number = team number (1 in example above)
P/E = Production / Engineering     2nd number = individual identifier
F/M = Front-line / Management

Arrows point from a participant to the team members that they indicated in their network survey responses. The size of each participant is proportional to the number of people who chose them in the network survey.

Figure 10 Sociogram of Team Repair 2B’s information-receiving network in Company B
Participants are labelled with a code such as APF1_7
A/B/C = Company A / B / C 1st number = team number (1 in example above)
P/E = Production / Engineering 2nd number = individual identifier
F/M = Front-line / Management

Arrows point from a participant to the team members that they indicated in their network survey responses. The size of each participant is proportional to the number of people who chose them in the network survey.

Figure 11 Sociogram of Team Repair 2B’s advice-seeking network in Company B
Participants are labelled with a code such as APF1_7
A/B/C = Company A / B / C 1st number = team number (1 in example above)
P/E = Production / Engineering 2nd number = individual identifier
F/M = Front-line / Management

Arrows point from a participant to the team members that they indicated in their network survey responses. The size of each participant is proportional to the number of people who chose them in the network survey.

Figure 12 Sociogram of Team Install 1B’s information-receiving network in Company B
Figure 13 Sociogram of Team Install 1B’s advice-seeking network in Company B

Participants are labelled with a code such as APF1_7
A/B/C = Company A / B / C 1st number = team number (1 in example above)
P/E = Production / Engineering 2nd number = individual identifier
F/M = Front-line / Management

Arrows point from a participant to the team members that they indicated in their network survey responses. The size of each participant is proportional to the number of people who chose them in the network survey.
Participants are labelled with a code such as APF1_7
A/B/C = Company A / B / C
1st number = team number (1 in example above)
P/E = Production / Engineering
2nd number = individual identifier
F/M = Front-line / Management

Key:
- Team member
- Supervisor
- Bridge builder
- Chose bridge builder
- Isolate
- Did not chose manager

Arrows point from a participant to the team members that they indicated in their network survey responses. The size of each participant is proportional to the number of people who chose them in the network survey.

Figure 14 Sociogram of Team Install 2B’s information-receiving network in Company B
Participants are labelled with a code such as APF1_7
A/B/C = Company A / B / C  
1st number = team number (1 in example above)
P/E = Production / Engineering 
2nd number = individual identifier
F/M = Front-line / Management

Arrows point from a participant to the team members that they indicated in their network survey responses. The size of each participant is proportional to the number of people who chose them in the network survey.

Figure 15 Sociogram of Team Install 2B’s advice-seeking network in Company B
Table 11 Network densities of teams for Company B

<table>
<thead>
<tr>
<th>Team</th>
<th>Advice-seeking density</th>
<th>Information-receiving density</th>
</tr>
</thead>
<tbody>
<tr>
<td>Team Repair 1B</td>
<td>0.28</td>
<td>0.05</td>
</tr>
<tr>
<td>Team Repair 2B</td>
<td>0.13</td>
<td>0.05</td>
</tr>
<tr>
<td>Team Install 1B</td>
<td>0.26</td>
<td>0.08</td>
</tr>
<tr>
<td>Team Install 2B</td>
<td>0.33</td>
<td>0.24</td>
</tr>
<tr>
<td>Mean</td>
<td>0.25</td>
<td>0.11</td>
</tr>
</tbody>
</table>

Table 15 and Table 13 contain summaries of the ego-level statistics of the workers in Company B. The ego-level statistics of 44 participants were calculated based on their responses to the social-network survey. 2 managers’ responses were constructed based on their answers to interview questions. The EI-index and out-degree of front-line workers showed that they primarily received information, and would ask for advice, from within their team. Across all participants the total external tie count was only 27 for information-receiving, and 46 for advice-seeking. For both network types the most common external tie was an engineer from the safety assurance team, mentioned by 13 actors in both network types. [redacted]. This reinforces the initial interpretation of the organisation sociograms: both advice-seeking and information-receiving networks were built around a few key actors who possessed specific formal roles. This importance of formal positions on network structure could be a reflection of the different nature of work undertaken by Company B engineers. The engineers at Company B primarily worked individually at the location of the customer. This type of isolated work would create few opportunities to informally bond and learn colleagues’ specific areas of expertise.
Table 12 Ego-level size statistics for Company B

<table>
<thead>
<tr>
<th>Job type</th>
<th>n</th>
<th>Advice-seeking</th>
<th>Information-receiving</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Internal out-degree</td>
<td>External out-degree</td>
</tr>
<tr>
<td></td>
<td></td>
<td>M</td>
<td>SD</td>
</tr>
<tr>
<td>Engineering</td>
<td>44</td>
<td>6.25</td>
<td>5.69</td>
</tr>
<tr>
<td>Front-line</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Engineering</td>
<td>2</td>
<td>0.50</td>
<td>0.71</td>
</tr>
<tr>
<td>Management</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>46</td>
<td>6.00</td>
<td>5.69</td>
</tr>
</tbody>
</table>

Table 13 Ego-level diversity statistics for Company B

<table>
<thead>
<tr>
<th>Job type</th>
<th>n</th>
<th>Advice-seeking</th>
<th>Information-receiving</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>El-index</td>
<td>IQV</td>
</tr>
<tr>
<td></td>
<td></td>
<td>M</td>
<td>SD</td>
</tr>
<tr>
<td>Engineering</td>
<td>44</td>
<td>-0.65</td>
<td>0.55</td>
</tr>
<tr>
<td>Front-line</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Engineering</td>
<td>2</td>
<td>0.65</td>
<td>0.47</td>
</tr>
<tr>
<td>Management</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>46</td>
<td>-0.63</td>
<td>0.56</td>
</tr>
</tbody>
</table>

Figure 16 and Figure 17 show box plots of the distributions of El-indexes and IQV values for advice-seeking networks and information-receiving networks respectively in Company B.
While only limited conclusions can be made about the relationships of managers at Company B due to the small sample size, Table 15, Table 13, and Figure 16 suggest that the managers in Company B were unlikely to approach members of their own team to ask advice on safety-related issues. Their highly positive EI-index for advice-seeking demonstrates that managers were more likely to ask for advice from outside their own team. Both managers in fact listed the team’s designated safety engineer or that safety engineer’s manager as the people they would approach for advice. The EI-index of the information-receiving network indicates that both managers exclusively received formal information on incidents from sources external to their team.

Table 13, as well as Figure 16 and Figure 17, provide additional evidence for the narrative of the front-line workers being connected pre-dominantly only to engineers within their own
team. Figure 16 and Figure 17 show that the median EI-index for both advice-seeking and information-receiving information networks was -1.00. In other words, both formally and informally information on safety, including incidents, was only being exchanged with people on their own team. The same figures also highlight that the median IQV value was 0.00, indicating completely homogenous ties.

It should be noted, nonetheless, that despite the consistent story told by the sociograms and ego-level statistics, the standard deviation of all measures was relatively high. When comparing the densities of the four teams in Table 11, Team Install 2B appeared to have a more densely connected information-receiving network than the other teams, while Team Repair 2B’s advice-seeking network was more sparsely connected. Taken together this indicates that even within the same organisation, there was still a large amount of variation that is likely due to each team’s circumstances.

**Company C**

Figures 24 to 27 show the sociograms for the teams with the densest and least dense networks in Company C. In general, as shown by the network densities in Table 14, teams in Company C appeared to have dense advice-seeking networks, with a mean density of 0.81. [redacted], and, as already noted, high relative to network densities observed in other professional settings (e.g., Palonen et al., 2004; L. Zhang et al., 2012).

The information-receiving networks of Company C followed the pattern of Company B, as they were less densely connected than the advice-seeking networks. The information-receiving networks of Company C were, nonetheless, [redacted]. As with the other two organisations, the team supervisor was key for distribution of formal safety-related information, including incident-information within a team.

Figure 20 and Figure 21 show a very different pattern to the majority of teams in Company C, with a density of just 0.52 for their advice-seeking network; which was relatively low compared to other teams in Company C, although still approximately double the most connected advice-seeking network in Company B. This team represented a unique situation in Company C, as it was the combination of two areas that, while situated still on the same site as the other teams, were at the geographical edge of the site. From Figure 20 it can be seen that the team supervisor of one of the areas, the overall team supervisor of the entire team, was the only connection to CFA7_1 and CFA7_2 in the information-receiving network, nominating CFA7_1 as a person from whom they would receive information. Interestingly this was not mirrored in the advice-seeking
network. In the advice-seeking network the bridge builder of the larger area, i.e., the person most people would go to for some advice on a safety concern, was the only connection between the two groups, indicating that he would approach the other area for advice.
Participants are labelled with a code such as CPFB2_7
A/B/C = Company A / B / C   Letter + number = shift and team number (e.g. B2)
P/E = Production / Engineering 2nd number = individual identifier
F/M = Front-line / Management

Arrows point from a participant to the team members that they indicated in their network survey responses. The size of each participant is proportional to the number of people who chose them in the network survey.

Key
- Team member
- Supervisor

Figure 18 Sociogram of Shift B Team 2C’s information-receiving network in Company C
Participants are labelled with a code such as CPFB2_7
A/B/C = Company A / B / C  Letter + number = shift and team number (e.g. B2)
P/E = Production / Engineering  2nd number = individual identifier
F/M = Front-line / Management

Arrows point from a participant to the team members that they indicated in their network survey responses. The size of each participant is proportional to the number of people who chose them in the network survey.

Figure 19 Sociogram of Shift B Team 2C’s advice-seeking network in Company C
Participants are labelled with a code such as CPFB2_7
A/B/C = Company A / B / C  Letter + number = shift and team number (e.g. B2)
P/E = Production / Engineering  2nd number = individual identifier
F/M = Front-line / Management

Arrows point from a participant to the team members that they indicated in their network survey responses. The size of each participant is proportional to the number of people who chose them in the network survey.

**Figure 20 Sociogram of Shift A Team 7C’s information-receiving network in Company C**
Participants are labelled with a code such as CPFB2_7
A/B/C = Company A / B / C  Letter + number = shift and team number (e.g. B2)
P/E = Production / Engineering  2nd number = individual identifier
F/M = Front-line / Management

Arrows point from a participant to the team members that they indicated in their network survey responses. The size of each participant is proportional to the number of people who chose them in the network survey.

Figure 21 Sociogram of Shift A Team 7C’s advice-seeking network in Company C
Table 14 Network densities of production teams in Company C

<table>
<thead>
<tr>
<th>Team</th>
<th>Advice-seeking density</th>
<th>Information-receiving density</th>
</tr>
</thead>
<tbody>
<tr>
<td>Shift A Team 1C</td>
<td>0.72</td>
<td>0.46</td>
</tr>
<tr>
<td>Shift A Team 2C</td>
<td>1.00</td>
<td>0.50</td>
</tr>
<tr>
<td>Shift A Team 3C</td>
<td>0.59</td>
<td>0.26</td>
</tr>
<tr>
<td>Shift A Team 4C</td>
<td>0.64</td>
<td>0.38</td>
</tr>
<tr>
<td>Shift A Team 5C</td>
<td>0.71</td>
<td>0.24</td>
</tr>
<tr>
<td>Shift A Team 6C</td>
<td>1.00</td>
<td>0.43</td>
</tr>
<tr>
<td>Shift A Team 7C</td>
<td>0.52</td>
<td>0.20</td>
</tr>
<tr>
<td>Shift B Team 1C</td>
<td>0.79</td>
<td>0.71</td>
</tr>
<tr>
<td>Shift B Team 2C</td>
<td>1.00</td>
<td>1.00</td>
</tr>
<tr>
<td>Shift B Team 3C</td>
<td>0.94</td>
<td>0.28</td>
</tr>
<tr>
<td>Shift B Team 4C</td>
<td>0.81</td>
<td>0.41</td>
</tr>
<tr>
<td>Shift B Team 6C</td>
<td>1.00</td>
<td>0.45</td>
</tr>
<tr>
<td>Mean</td>
<td>0.81</td>
<td>0.44</td>
</tr>
</tbody>
</table>

Table 15 and Table 16 show the ego-level statistics for participants in Company C. The statistics are based upon the 86 respondents to the social network survey, and the answers of five interview participants who did not complete the survey. Table 15 shows that members of the management team had slightly more external connections than the front-line workers for both advice-seeking and information-receiving. However, compared to Company B, front-line and management were relatively even in terms of their total network size – both groups had multiple links within their teams and to people external to their immediate team.

This balance of external and internal ties for both front-line and management in Company C is further reflected in Table 16. For both advice-seeking and information-receiving the EI-index of the front-line employees was less negative than the front-line staff of Company B due to the larger numbers of connections to actors outside of the participants’ immediate teams. The opposite was true when examining the EI-index of the management of the three organisations. The engineering management of Company B had positive values, indicating that they were more likely to seek advice or receive information from actors external to their team. Members of the Company C management listed far more members of their own team whom they would seek advice or receive safety-related information from.

Furthermore, the IQV values between management and front-line workers were more closely aligned than in Company B. In Company B, the low IQV of the advice-seeking network of front-line employees, when combined with a negative EI-index, indicated that workers primarily would obtain advice from people in their team, with little input from others who might have a different perspective, such as the health and safety department. In contrast, the management of all three organisations, and the front-line employees of Company C, had an IQV value of 0.5 or
greater in their advice-seeking networks. In other words, not only were the front-line workers of Company C connected to more actors outside their team than other organisations, as shown in Table 15, but they would potentially receive input from a greater diversity of experiences than front-line workers in Company B. This access to diverse views can be beneficial in solving problems, however the maintenance of so many ties can equally be demanding as effort is required to sustain relationships (Palonen & Hakkarainen, 2014).

<table>
<thead>
<tr>
<th>Job type</th>
<th>n</th>
<th>Advice-seeking</th>
<th></th>
<th>Information-receiving</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Internal out-degree</td>
<td>External out-degree</td>
<td>Internal out-degree</td>
<td>External out-degree</td>
</tr>
<tr>
<td></td>
<td></td>
<td>M</td>
<td>SD</td>
<td>M</td>
<td>SD</td>
</tr>
<tr>
<td>Production Front-line</td>
<td>83</td>
<td>6.16</td>
<td>1.99</td>
<td>3.67</td>
<td>3.44</td>
</tr>
<tr>
<td>Production Management</td>
<td>8</td>
<td>8.00</td>
<td>9.89</td>
<td>4.00</td>
<td>2.93</td>
</tr>
<tr>
<td>Total</td>
<td>91</td>
<td>6.32</td>
<td>3.39</td>
<td>3.70</td>
<td>3.39</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Job type</th>
<th>n</th>
<th>Advice-seeking</th>
<th></th>
<th>Information-receiving</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>EI-index</td>
<td>IQV</td>
<td>EI-index</td>
<td>IQV</td>
</tr>
<tr>
<td></td>
<td></td>
<td>M</td>
<td>SD</td>
<td>M</td>
<td>SD</td>
</tr>
<tr>
<td>Production Front-line</td>
<td>83</td>
<td>-0.35</td>
<td>0.42</td>
<td>0.50</td>
<td>0.28</td>
</tr>
<tr>
<td>Production Management</td>
<td>8</td>
<td>0.08</td>
<td>0.59</td>
<td>0.62</td>
<td>0.17</td>
</tr>
<tr>
<td>Total</td>
<td>91</td>
<td>-0.31</td>
<td>0.45</td>
<td>0.51</td>
<td>0.27</td>
</tr>
</tbody>
</table>
Finally, it can be observed from Table 15, Table 16, Figure 22, and Figure 23 that, as with the ego-level statistics of Company B, the range of all measures was relatively high. This is likely to indicate that there was a large amount of variation between workers depending on their exact role and situation.

**Key findings of quantitative analysis**

A summary of the network densities for all three organisations is shown in Table 17. A summary of the ego-level statistics related to network diversity are shown in Table 18.
The first key finding from the quantitative analysis of networks, as can be seen from Table 17, is that two patterns of within team connectivity were observed. In Company C, the teams of front-line operators were highly connected in terms of advice-seeking. In Company B, on the other hand, a few select team members were far more likely to be contacted for advice than other workers. These team members with a high in-degree also possessed some kind of formal role within the team: either a team supervisor or a coach. These patterns may be due to the geographical distance between members, as Company B workers carried out their jobs in separate locations to each other, and correspondingly would be more likely to need to rely on formal titles to know the expertise of their colleagues, as there would be less opportunities for face-to-face interactions.

[redacted] the information-receiving networks were less densely connected than the advice-seeking networks. Similar to Company B’s advice-seeking network, the central actors in these networks corresponded to those with specific formal roles. This implied that the team supervisors, and supporting workers such as coaches or deputy-supervisors, were vital for bridging the wider organisation and the front-line workers. If these key actors did not receive incident-information, or were not skilled in communicating it to their team, then the front-line workers may not know anything about a particular incident. This reliance on team supervisors could be a risk, as during the supervisor’s holidays or sick leave the team would likely miss access to relevant incident-related knowledge.

The second key findings can be garnered from examination of Table 18, examining the ties between workers and actors external to their immediate team. [redacted] the management group had a greater number of connections external to their team that the front-line workers, as evidenced by their more negative EI-indexes. Additionally, management had larger IQV values,
indicating a greater diversity in their networks. This pattern was observed [redacted] in both advice-seeking and information-receiving networks. This has two implications: that when they needed advice, management had access to a greater range of perspectives, and that there were more opportunities for them to encounter incident-information. As there were key team members who the majority of the front-line team were dependent upon for formal incident-information, it would be beneficial to ensure team supervisors were well connected to managerial colleagues to ensure that the front-line staff’s behaviour can benefit from insights and information granted by the diverse network of the management.

A nuance to this finding can be observed from a comparison between Company C and Company B. While the same general trend was observed between the networks of management and front-line workers, the ego-level statistics of front-line workers and management were more similar than within Company B. While it was not clear from the quantitative analysis alone why this is the case, this greater number of external connections outside their immediate team would allow Company C front-line workers to be less dependent upon their team supervisor for incident-information. This difference in network structure could, however, come with a trade off in terms of the time and effort needed for Company C workers to maintain these relationships.

The final finding of the quantitative analysis was the great diversity within networks. For all ego-level statistics there was a large standard deviation. This implies that the circumstances of the individual worker affected the network structures of the organisations. Potential influencers will be explored in the following section detailing the results of the qualitative analysis.

5.3.2 Qualitative Findings

Information dissemination

In terms of dissemination, all 45 interview participants [redacted] mentioned that they received a large amount of information regarding incidents. Distributed incident-information consisted of details of local incidents from their sites, other sites in the same organisation, and the industry in general. Information was distributed by a variety of well documented formal tools, which were similar in all the organisations. Participants in Company C also spoke about how the formal dissemination was supplemented by unstructured interactions. One participant described the way that they received information as:
'So you know it’s, it’s a mixture of, the official way is by email. But we also get the less formal sort of verbal mentions, if you like'

Participant C12, Front-line
Advice seeking: Internal size = 7; External size = 3; El-Index = -0.40; IQV = 0.64
Information receiving: Internal size = 7; External size = 3; El-index: -0.40; IQV: 0.64

In general, in all organisations information on incidents was cascaded from the health and safety department to the production or engineering management. This in turn was passed on to team supervisors, who would subsequently inform their team during regular meetings. Supervisors received information from either emails, meetings, or entries into the incident reporting database. Additionally, regular meetings were held at all organisations between front-line teams and the safety department. At the managerial level all organisations appeared to have regular meetings that would bring different teams and departments together to disseminate and discuss incidents. Table 18 showed that managers on average had more ties external to their immediate teams and a less homogenous network in relation to information-receiving than front-line workers. Participation in multi-disciplinary meetings is likely one reason for this greater network diversity.

Some redundancy in communication was noted in both Company B and Company C. In Company C the shift supervisor, the heads of technical areas, and shift safety teams would all pass information on to team supervisors. Participants felt that this was a beneficial practice, as it was a form of ‘double checking that we haven’t missed anything’ (Participant C13, Front-line). Conversely, in Company B participants felt that they were unnecessarily instructed to look at the same information multiple times:

‘He sends us a million and 12 emails a day about everything. And you might even get a text message about it as well. And then a WhatsApp to tell you that to check your text messages to check the email’

Participant B10, Front-line
Advice seeking: Internal size = 1; External size = 1; El-Index = 0.00; IQV = 0.75
Information receiving: Internal size = 1; External size = 1; El-index: 0.00; IQV: 0.75
However, in Company C not all incident-information distributed by the health and safety department made its way to front-line workers. Various judgements were made at each level of the cascading process about who the information was most relevant to. For example, in Company C initially a team made from members of the health and safety department, human factors department, and production management team selected the most relevant incidents that they had received from any source, such as internal incident reports, or professional organisations. The reason for this was ‘because a lot of information comes through which the operators don’t need to know.’ (Participant C1, Management). [redacted]

The multiple pathways through which incident-information was distributed meant that participants received an abundance of information:

“We don't go out of our way to find this information out, it's put in front of your face”

Participant C10, Front-line

Advice seeking: Internal size = 1; External size = 4; EI-Index = 0.60; IQV = 0.43

Information receiving: Internal size = 1; External size = 1; EI-index: 0.00; IQV: 0.67

It should be noted that formally incident-information appeared to flow from the top of the organisations to the bottom, besides the submission of an initial incident report. Participants from the front-line of [redacted], as will be discussed under the following ‘information gathering’ section, mentioned that sometimes feedback was requested on particular incidents. However, it did not appear to be a standard feature and participants noted that they rarely received responses to feedback provided. In the quantitative analysis of the organisational networks those with formal authority within a team appeared to be vital for ensuring teams received formal incident alerts. This interpretation was supported by participants primarily describing themselves as recipients of incident-information, rather than taking an active part in discussions around its relevance to the organisation outside of their immediate team. The qualitative analysis of information dissemination networks corroborates the finding of the quantitative analysis in the bridging role played by the team supervisors.

Information gathering

Information gathering generally took three forms: incident investigations, gathering formal feedback, and asking advice. All workers could enter a report into the incident reporting system. A
team would then decide on the risk of the incident, and what kind of follow-up was required. In Company C, for example, two different types of information gathering activities could be initiated following this risk ranking. The first was an after-action review, where an investigation team was created including the person involved in the incident, their supervisor, and the health and safety department. Information on the incident was gathered by this team and updated in the reporting system. The second type of information gathering activity was a root cause analysis, where the causes of the incident were examined in-depth using specific techniques by trained personnel. Initial reports following incidents were often presented in meetings to gather feedback and possible insights:

“I mean in this meeting it's not just operators in there, so you've got engineers in there. We have safety guys in there. A mix and match of everybody from operators to [day supervisors].”

Participant C13, Front-line

Advice seeking: Internal size = 8; External size = 2; EI-Index = -0.33; IQV = 0.67

Information receiving: Internal size = 0; External size = 2; EI-index: 1.00; IQV: 0.00

[redacted] The incident investigation process of Company B differed in that after the initial report the incident would be taken forward by the engineer’s manager, the health and safety department, the union representative, and possibly the district manager. After the initial report the involvement of front-line workers in the investigation was limited. One participant was invited to interview as they indicated they wouldn’t approach their supervisor for advice. The participant explained that he had had bad experiences after reporting an incident to his manager. The participant felt that the response of the manager and the following investigation, which had been guided by organisational policy, had been disproportional to the actual incident. He clarified that he no longer trusted his manager not to panic by initiating a large-scale investigation for a minor incident.

[redacted] a digital record of the incident located in the reporting system was continuously updated; it could be accessed to check on the status of the investigation, or recall particular details that became relevant to future situations. The reporting system became a medium to facilitate communication between not just the investigation team, but anyone in the present or future who may have an interest in the incident. One participant described how he had accessed an incident report at a later date to justify his actions:
‘I went online and read the, the inquiry reports into what exactly happened and I said, and I printed it off and I underlined or highlighted various things where it was, I said, look it's exactly the same. We’re doing exactly the same as what they were doing.’

Participant C12, Front-line

Advice seeking: Internal size = 7; External size = 3; EI-Index = -0.40; IQV = 0.64

Information receiving: Internal size = 7; External size = 3; EI-index: -0.40; IQV: 0.64

This digital record also allowed workers to find information on incidents that had been viewed as irrelevant to their job role, and hence not distributed to them through formal channels. Although actively using the database seemed to vary greatly between participants.

A lack of engagement with the reporting database was particularly common with front-line participants who did not use computers during their daily tasks.

However, in Company B one participant described his experiences of an incident where he had been unable to access the investigation information after he created the initial report. The system in theory should have been visible to the employee, so it was unclear during the interview if the issue was due to a lack of knowledge of where to find the incident, or a problem with the settings of the incident reporting system.

[redacted] the severity of the incident impacted the transparency of the formal information available:

‘It was all a bit, not cloak-and-dagger, but obviously it was a lot more secretive than what would normally be expected on a normal smaller one’

Participant C1, Management

Advice seeking: Internal size = 1; External size = 1; EI-Index = 0.00; IQV = 0.67

Information receiving: Internal size = 0; External size = 4; EI-index: 1.00; IQV: 0.67
Nonetheless, managers noted that they could gather additional information informally using their connections and networks:

[redacted]

Management in Company C also mentioned using their professional networks to gather information on additional incidents to those distributed by the health and safety department. Although no management-level workers mentioned this in Company B, this was possibly due to only interviewing two participants from this group. For example, one participant in Company C described an experience of attending an external conference where another organisation presented on an incident and its consequences. This became a stimulus for the audience of the presentation, who were representatives from multiple organisations, to discuss how they would handle similar situations, resulting in the trial and eventual implementation of a process change at Company C. While outside the structured information dissemination pathways of the organisation, participation in conferences or professional networks represented purposeful efforts by managerial-level workers to learn about relevant incidents. This flow of incident-information is represented in Figure 24.

![Diagram: Formal information-dissemination vs. Non-formal information-gathering]

*Figure 24 Incident-information flow in organisations*

The purposeful cultivation of contacts, along with more opportunities to join multi-disciplinary teams discussing incidents is a potential explanation for the greater number of external connections, i.e., more positive EI-indexes, and greater diversity of connections, i.e., larger IQV values, of managerial workers compared to front-line workers observed in Table 18.

Besides information gathering being an integrated part of a formal incident investigation, feedback was also gathered by a range of workers on different ideas related to incident prevention. In Company C feedback could be gathered after receiving one of the official incident
presentations. Workers saw providing this feedback as a natural process. One participant said ‘we’ve got our safety department, but they’re not out all over the place all of the time. Whereas operations are’ (Participant C5, Front-line). Correspondingly, participants felt that it was important to give feedback to ensure that the health and safety department were well informed about different perspectives on an incident. None of the participants in Company B mentioned a similar request following a presentation on an incident, although there were opportunities to ask questions and clarify understanding. Nonetheless, three participants of Company B described the ability to submit feedback in a different way: through a digital platform that provided them with information on potential equipment faults and historical records of the task location. If an engineer discovered that information was incorrect on equipment specifications, they could submit suggested amendments which would be reviewed by a separate team and potentially accepted.

In terms of gathering advice, the experiences of management and front-line workers differed. Some managers in Company B felt that they were limited by their hierarchical position in terms of who they could approach for feedback. [redacted]

A manager in Company B also described a similar situation, where he would only contact his team about an issue to understand how widespread a misconception appeared to be. Management in Company C, conversely, appeared to be happy to approach front-line workers for their opinions, and to understand why tasks were carried out in a particular manner. One team supervisor described how a new member of his team had proven himself to be extremely competent and knowledgeable, thus becoming a valuable person to ask for advice despite inexperience.

For front-line participants, several factors influenced who they approached for advice. In general advice-seeking was influenced by physical closeness, perceived expertise, and the authority to influence change. In Company C most front-line participants felt they would approach anybody for advice, and would often get a second opinion from whoever was closest. [redacted]

In Company B participants did not work in close physical proximity to each other and would contact whoever they felt had the most expertise in an area. For concerns over potential incidents this would usually be the safety assurance engineer assigned to the team:

‘He basically knows everything there is to know about safety and he’s always available.’

Participant B4, Front-line

Advice seeking: Internal size = 5; External size = 1; EI-Index = -0.67; IQV = 0.42
Information receiving: Internal size = 1; External size = 1; EI-index: 0.00; IQV: 0.75

Other team members might be contacted for advice, but in a selective way:

‘So I wouldn’t just phone any engineer on my team I would just phone ones who I thought were good.’

Participant B10, Front-line

Advice seeking: Internal size = 1; External size = 1; EI-Index = 0.00; IQV = 0.75

Information receiving: Internal size = 1; External size = 1; EI-index: 0.00; IQV: 0.75

The sociograms for Company B were less densely connected than those in Company C. These qualitative findings indicate that the close physical proximity of those in Company C plays a large role in the dense advice-seeking network of these organisations. However, rather than each team member being interchangeable, the advice of most team members appeared to be a second opinion on the way to bringing issues to the team supervisor. In Company B those perceived as possessing the most relevant knowledge were contacted for advice, which explains the more sparsely connected advice-seeking networks, and why those with formal positions were contacted: they should possess the most knowledge on particular topics.

Sharing

Whilst networks were used intentionally for incident-information distribution and gathering, participants also described multiple occasions where incidents or potential incidents were discussed serendipitously; participants described a variety of ways in which ideas and opinions were shared through regular formal and informal interactions. These interactions provided opportunities to trade information on incidents, or best practices that had resulted from incidents, although that was not necessarily the explicit purpose of those interactions.

In Company C each team of front-line workers nominated a representative to attend cross-organisational meetings. For example, one member of each team attended a cross-shift meeting, where best practices and approaches to safety were shared. Another meeting provided an opportunity for those who worked in shift patterns to discuss issues with those in the office, who only worked during days. The discussions that took place at these meetings were shared.
through the representatives from each team, as well as through the minutes which were distributed to everyone. One participant remarked:

‘Even on the refinery area to area, you might do something different, you know. And it’s like that’s bloody obvious you don’t do it that way, but to them doing it, because they’ve always done it, they might not see it so’

Participant C6, Front-line
Advice seeking: Internal size = 6; External size = 4; El-Index = -0.50; IQV = 0.50
Information receiving: Internal size = 1; External size = 2; El-index: 0.33; IQV: 0.59

Participants at Company B did not mention similar opportunities to take part in such cross-organisation meetings on a regular basis. In the quantitative findings, as shown by Table 18, the networks of front-line participants in Company C appeared to be more diverse and less concentrated on each person’s immediate team. The opportunity for front-line workers to participate in meetings such as these is one possible explanation for this trend in network diversity. Nevertheless, participants in all three organisations spoke about sharing information and best practice within their teams. In Company B one participant described how team meetings became opportunities to share:

‘You know, somebody says... why did you do that? Well because it came out the other day that this happened so I’ve changed the way I do it now. So, you know, it gets picked up like that. And again, if it’s a more experienced engineer, the less inexperienced engineers tends to follow them.’

Participant C3, Front-line
Advice seeking: Internal size = 1; External size = 4; El-Index = 0.60; IQV = 0.43
Information receiving: Internal size = 1; External size = 1; El-index: 0.00; IQV: 0.67

The managerial team at all three organisations also participated in similar meetings at the organisational level. For example, each of the team supervisors in Company B met with their district counterparts on a monthly basis to share issues and ideas. [redacted]
Besides formal meetings, semi-formal opportunities were created for spontaneous exchanges of relevant information. [redacted]

While the LFI process is often depicted as a linear and purposeful process, the interviews provided evidence that the formal process is supported by continuous and spontaneous sharing of best practices and insights from incidents.

**Contextualising**

Whist the information disseminating, gathering, and sharing themes discussed above highlighted that participants used their networks to ensure that the right people had the right information, the ‘contextualising’ theme related to how networks allowed people to understand the information that they had received. Safety meetings, already noted as important for disseminating incident-information and enabling sharing, were also described as an opportunity to contextualise information through discussion, and ‘healthy debates’ (Participant C7, Front-line). In Company C this was often cited as happening through linking incidents to the procedures and processes in place at Company C. One team supervisor commented about the way that he ran his team meetings:

‘I actually asked them what they would do differently. How they would have, how they would have approached the task that caught this person out. How would you have done that then? How would you have avoided being caught in that trap?’

*Participant C3, Front-line*

Advice seeking: Internal size = 1; External size = 4; El-Index = 0.60; IQV = 0.43

Information receiving: Internal size = 1; External size = 1; El-index: 0.00; IQV: 0.67

Equally team meetings provided opportunities to add their own personal experiences of when similar events to the incident under discussion had occurred:

‘I think you know if you have any, anything that you can directly relate to, something that you’ve been through, you can bring it up or if you have any questions or concerns you can sort of speak your mind a little bit.’

*Participant B6, Front-line*
Advice seeking: Internal size = 1; External size = 1; EI-Index = 0.00; IQV = 0.75
Information receiving: Internal size = 0; External size = 1; EI-index: -1.00; IQV: 0.00

[redacted]

All organisations provided repositories of information on procedures, protective equipment, and so on. Two front-line participants at Company C mentioned consulting these in order to reflect on how incidents related to their own work. In Company B one participant, a coach for his team, described how when contacted by his peers for advice he tried to guide them on how to find that information in the repositories, to help them to find information if they needed it in the future:

‘I always tell them to look up [procedure database]... I want them to look up [procedure database] so they know where to find it... Rather than me giving them the answer straight away, which I know the answer but they need to find out themselves because if I’m not around because I’m on holidays or somebody else or somebody was on training they weren’t around, they have to find out for themselves.’

Participant B9, Front-line

Advice seeking: Internal size = 19; External size = 0; EI-Index = -1.00; IQV = 0.00
Information receiving: Internal size = 19; External size = 0; EI-index: -1.00; IQV: 0.00

Management, conversely, used their connections within the organisation to evaluate risks. For example, by asking a specialist for their advice on an element of an incident outside their own knowledge:

‘Then you’d go to the best people, the relevant people that way. Talk to the areas, talk to the subject matter experts and go through that’

Production C5, Management

Advice seeking: Internal size = 1; External size = 3; EI-Index = 0.50; IQV = 0.50
Information receiving: Internal size = 1; External size = 4; EI-index: 0.60; IQV: 0.85
Meetings between participants in management aided contextualisation, in a similar way to the safety meetings held by the front-line at the start of each shift. Meetings provided an opportunity for management colleagues to draw together their experiences, evaluating which incidents posed a real threat to current activities.

[redacted]

5.4 Discussion

Chapter 5 detailed the results of a mixed methods social network analysis across three organisations and 173 participants designed to describe network structures that support LFI, and then explore the functions that these networks have in learning. To the best of my knowledge, this thesis is the first to conduct SNA in relation to LFI, and one of few studies that have collected data on communication of safety related information across multiple organisations.

The structure of advice-seeking networks in teams followed one of two patterns: densely connected to almost everyone in the team, or connected to a few key actors perceived as having expertise due to their job role. Formally information primarily entered the team through those with authority, such as the team supervisor or safety assurance engineer. Managerial-level workers had a greater number of connections to those outside their immediate team, and a more diverse network in general. However, there was a large amount of variation within groups. Physical proximity to other colleagues and opportunities to participate in either cross-organisational meetings or professional networks appeared to be two major influencers on network structures and dynamics.

In terms of how networks enabled learning using incident-information, there were three ways that networks enabled workers to exchange information: cascading through a series of managerial levels; gathering feedback and advice; and unprompted sharing of experiences and knowledge. Furthermore, networks allowed workers to understand the relevance of incidents and contextualise them to their own work. As was seen in the narratives that accompanied each type of information-exchange, the network structure played a key role in deciding what incident-information workers had access to, and subsequently how they connected that information to their own practice.
5.4.1 Network Structures

Prior research on networks within workplaces has highlighted that there is no single ideal structure, rather the optimal density and diversity of connections will be dependent upon the context of the workplace (Hakkarainen et al., 2004). However, the structure, pathways and affordances of networks are important considerations of the learning presage (Tynjälä, 2013). As discussed in the selection criteria in Section 4.9, all the organisations in this thesis had mature LFI processes, and yet three distinct network profiles were observed. In Company C, teams of frontline workers in production appeared to be densely connected. Theoretically this would allow the exchange of complex and tacit information between team members, beneficial in a technical environment such as the energy sector (Nonaka & Takeuchi, 1995). These can be considered as strong ties, however, it is often the weak ties, i.e., connections not necessarily with someone with whom work is conducted on a daily basis, that can bring new information and perspectives, enabling creativity (Borgatti & Lopez-Kidwell, 2015; Daly & Finnigan, 2011).

While the network-level sociograms of Company C told a similar story, the ego-level statistics showed a difference in the way that information was shared and distributed externally to the team, the connections that were far more likely to be weak than those within the team [redacted] In Company C, on the other hand, the front-line operators had more external ties, meaning that they were likely to discover information on incidents from others besides their supervisor. Moreover, research on the role of networks has demonstrated that external connections can bring new knowledge into groups, and allow issues to be examined by a wider collection of perspectives (Ahuja, 2000), which in turn is beneficial for learning in groups (Mercer, 2013). Hence, the more diverse connections of front-line workers in Company C should bring two advantages: access to larger quantities information, and more diverse perspectives for reflection. This aligns well with the dissemination and contextualising phases of the LFI process (Margaryan et al., 2018). The qualitative analysis highlighted that many meetings designed to enable sharing between different departments took place in Company C. However, this creation of opportunities takes time and resources to implement (Daly & Finnigan, 2011). There is a theoretical balance that needs to be considered between the benefits that diverse networks of front-line workers could bring, and the costs of creating opportunities to nurture cross-organisational networks. In Company C the management-level workers possessed diverse network ties. If the team supervisor is well connected to the management, there may not be a need for the whole team to have diverse connections in order to ensure they have access to incident-information from multiple sources. As described in Section 3.2.2, this is the hub and spoke network model that is efficient in terms of maximising information distribution for minimum investment of resources. However,
there is a risk that if the supervisor became unavailable, for instance, due to illness or being on vacation, then a large portion of the team’s knowledge becomes unavailable as no other team member has access to the same informational resources. This is particularly worrying in a safety context, as decisions need to be made in rapidly changing situations where a wrong decision could have devastating consequences (M. A. Sujan et al., 2016).

While Company C differed primarily in the external network connections of front-line workers, Company B’s sociograms showed a substantially different within team structure, which very closely resembled the hub and spoke model. In Lukic et al.’s (2012) framework of LFI it was purported that locative knowledge, i.e., understanding where information can be accessed when needed, was important for LFI. As the nature of Company B’s work meant that its engineers rarely met face-to-face, formal roles in the organisation were designed to explicitly label expertise, with titles such as ‘safety assurance engineer’. This was reflected in the organisation’s sociograms, as certain team members were more central than others. A network structure such as this has the advantage of being very efficient does not necessarily mean that workers have less access to information if the gatekeepers are themselves well connected (Daly & Finnigan, 2011), although the benefits of contextualising information through discussion with a multitude of perspectives are likely to be limited (Mercer, 2013).

The quantitative analysis [redacted] highlighted the key role that the team supervisor played in the distribution of incident-information. As the front-line teams in all three organisations, but especially in Company B, had few connections external to their team they were reliant on their team supervisor for providing them with information. The team supervisor therefore would need to be skilled at sharing information, but should also be well connected to managerial-level workers. This is particularly important given the central position of the team supervisor in the advice-seeking network, in other words, as the team supervisor was often the first or second person that a worker would approach with an issue. The large and diverse networks of the managerial-level workers should facilitate gathering a broad range of incidents. Nonetheless, if insights from these incidents are not passed on to the front-line workers, who perform the actual tasks, then these insights may go to waste. In all organisations the team supervisor represented the most efficient path to the front-line workers. However, in Company C this was offset slightly by front-line workers being connected to three or four others from outside their team. As the qualitative analysis highlighted that incident-information is exchanged outside of the formal distribution mechanisms the reduced reliance on the team supervisor meant that Company C front-line workers would have the possibility of participating in these information-exchange activities, whereas it is unlikely that the same was true in Company B.
It should be noted that while the network structures differed between Companies B and C, there was also a large amount of diversity within networks. [redacted]. Equally, even in organisations where front-line workers are connected only to their own team, the size of the teams can vary greatly between different processes or different shifts. This would impact the amount of collective experience that can be drawn upon. Organisations can consider the optimal information dissemination strategies for their situations, but the networks of individuals will likely vary greatly depending upon job type, team size, and even personality (Licorish & Macdonell, 2015; Venkataramani et al., 2016). In particular, organisations should pay attention to isolates that arise, such as those seen in teams from Company B or Shift A Team 7C in Company C, where the physical location of a worker’s tasks isolate them. While it may not always be possible to have workers near each other, organisations can ensure that there are opportunities, such as inter-departmental meetings, where they can enrich their own connections and access to incident-information.

5.4.2 Information-Exchange

The qualitative analysis of the social network data revealed that networks were used by participants in three of the steps in the LFI process: investigating, disseminating, and contextualising (Drupsteen et al., 2013; Littlejohn et al., 2017). The role of networks in the investigating step was primarily functional in gathering evidence on incidents, and was described by participants in a similar manner to other literature on incident investigations (J. E. Anderson & Kodate, 2015; Nicolini et al., 2011a). In contrast, the three types of network utility inductively generated through the analysis relating to information flow, i.e., information dissemination, gathering, and sharing, began to unpack the nuances of communicating incident-information that has been highlighted as a gap in the literature (Drupsteen & Guldenmund, 2014; Lindberg et al., 2010). All three categories relate to ensuring that the right information reaches the right people using different formal and informal mechanisms, and with a varying degree of purposefulness. While receiving information is not the same as learning (Margaryan et al., 2017), it can be considered as the first step in potentially enabling workers to learn (Biesta & Burbules, 2003).

While the majority of studies on LFI have focused on the formal mechanisms for distributing incident alerts, some have highlighted the importance of informal learning (e.g., Vastveit et al., 2015). In the 3-P mode of workplace learning, part of the theoretical framework of this thesis discussed in Chapter 3, distribution of information could be considered as part of the learning process (Tynjälä, 2013). While three different ways of exchanging incident-information
emerged from the data in this analysis they could be considered categories of different types of information-exchange activities that fit on a scale between formal and informal. Additionally, each information-exchange activity possessed other characteristics such as how purposeful and spontaneous the exchange was. These other dimensions closely resembled the typology of informal learning in the workplace proposed by Eraut (2000, 2004). Whilst learning in the workplace is associated with formal interventions, learning can be considered as consisting of various dimensions such as whether the learning is implicit or purposeful, and whether it takes place within deliberate formal structures or while conducting daily work (Manuti et al., 2015; Tynjälä, 2008). Eraut (2004) proposed three dimensions of informal learning in professional contexts: implicitness, deliberativeness, and reactivity. Informal learning should be considered as a continuum on these three dimensions rather than discreet categories, as discussed in Section 2.3.2. The information dissemination function of networks was primarily a top-down and formal approach to distributing information to enable learning. Information gathering, on the other hand, comprised some formal aspects such as requesting feedback on proposed changes following incidents, but also entailed some activities that would be similar to reactive learning, such as asking for advice when encountering an unexpected situation. The sharing theme most closely resembled implicit learning as it was often unstructured with no expectations of future actions.

While this thesis deals with learning from incident-information, networks play a key role across workplace contexts in ensuring that workers in general exchange information. Eraut's (2004) typology can be expanded, as shown in Table 19, to a typology of information-exchange activities in professional settings.
Table 19 Typology of information-exchange activities in professional settings

<table>
<thead>
<tr>
<th>Dimension</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Formality</td>
<td>Does the information-exchange involve formal mechanisms, such as professional groups or meetings?</td>
</tr>
<tr>
<td>Direction of information flow</td>
<td>Is the information moving through hierarchal rankings in the organisation, such as from the top to the bottom, between peers, or some other combination?</td>
</tr>
<tr>
<td>Deliberativeness</td>
<td>Is the information being shared in a deliberate manner with the intention of supporting learning?</td>
</tr>
<tr>
<td>Reactivity</td>
<td>Is the information being shared in response to certain stimuli, such as an unexpected situation, or continuously in a regular manner?</td>
</tr>
<tr>
<td>Explicitness</td>
<td>Are learners aware that they are gaining information?</td>
</tr>
</tbody>
</table>

The results of the qualitative analysis of this chapter supported studies which have highlighted the importance of informal learning in LFI (Gartmeier et al., 2017; Vastveit et al., 2015). While the LFI process models of Littlejohn et al. (2017) and Drupsteen et al. (2013) map out the formal procedure for LFI, there is a need for more focus on the part of the learning process that is less explicit and controlled. Lukic et al. (2012) expanded their original framework (Lukic et al., 2010) to include the formality of learning. Despite this, the informal mechanisms by which incident-information spreads, either through working together with someone whose actions have already been influenced by incident-information or when encountering an unexpected situation, are still poorly understood. The typology presented here could be used a starting point on which to build a better understanding of these aspects of the learning process.

5.4.3 Networks and Learning

When considered from the perspective of the 3-P model of workplace learning (see Section 3.7) the analysis in this chapter has offered insights into several aspects of learning. Analysis of the network structures offers a perspective into the environment in which learning occurs, one element of the presage (Biggs, 1994). Additionally, the qualitative exploration of the interview SNA data has uncovered several elements related to how information is exchanged, activities that could be considered part of the learning process (Tynjälä, 2013). However, networks appear to play an additional role in the learning process by supporting workers in their reflection on incident-information.
The fourth theme from the qualitative analysis related to the contextualising step in the LFI process (Littlejohn et al., 2017). Research has shown that how workers understand and make sense of information and events is influenced by interactions with their peers (Billett, 2014; Yap & Choy, 2018). It is therefore logical that networks would play a role in how workers relate the incident-information that they receive to their own work. Socio-cultural theories of learning highlight that each individual brings their own history and perspectives with them to interactions, and that by discussing subjects with others assumptions can be highlighted and discussed in a critical manner (Emerson, 1983; Mercer, 2013). A diverse network could therefore allow workers access to ideas and viewpoints that enable them to learn from incidents. The knowledge possessed by an individual is comprised of both explicit and tacit elements, and discussion or conducting activities together can help to make explicit the tacit knowledge in order to benefit others (Nonaka & Takeuchi, 1995). Furthermore, from the perspective of contextualising there is a definitive benefit in having a diverse network to enhance reflection on safety information through dialogue (Yap & Choy, 2018).

Although the structure of networks matters as they will influence the type of information-exchange activities that workers engage in, they will additionally shape the conversations and discussions that workers take part in. In the interviews most participants mentioned that it was through discussion that they truly engaged with incident alerts. Network structures will therefore influence who is involved in conversations on incident alerts, and subsequently how workers make sense of that information. The analysis of network structures showed that teams of frontline workers were primarily connected to each other. This may limit the variety of backgrounds present in discussion, as teams slowly grow to implicitly have similar assumptions and values as their tacit knowledge develops through their similar tasks. Managerial-level workers, on the other hand, had more diverse networks; there would likely be more opportunities for managers to discuss incident alerts with those whose background was dissimilar to their own. Considering that the team supervisors appeared to be workers with the potential to bridge front-line and managerial workers, it would be vital that they take part in the incident discussions of managers to benefit from their diverse experiences.

Gressgård and Hansen (2015) theorised that contractors should enable knowledge-exchange. In their study knowledge-exchange was found to be significantly related to contractor relations. In light of the findings of this thesis, contractors could be enabling knowledge-exchange through engaging in discussions. Front-line workers are relatively isolated from those with different perspectives, but contractors would possess a different background and be able to better enhance discussions on incidents.
5.4.4 Limitations

Chapter 5 combined both quantitative and qualitative SNA to explore the structure and functions of networks. The results of this chapter are limited by SNA’s lack of consideration of context and culture, which will be addressed in Chapters 6 and 7. The methods of analysis employed in this chapter are additionally descriptive, unable to identify any hidden tensions in how workers engage with LFI, which will be addressed in Chapter 7. Another significant limitation of the analysis is that it relies upon self-reported data. The data collected through the social network survey enables the calculation of the network position of an individual through cross-checking of the answers of multiple participants, however, there is still no direct observation of the interactions of workers to verify that the sociograms and ego-level statistics are a reasonable approximation of reality. Observation studies would therefore be of benefit in the future.

Dialogue and discussion were highlighted by participants as important for contextualising the incident alerts which they received. As research has shown that meetings during the LFI process can vary greatly in implementation (J. E. Anderson & Kodate, 2015; Nicolini et al., 2011a) it would be beneficial if future studies explored how meetings that discussed incident alerts progressed and what appeared to aid workers in exploring the lessons learnt from investigations. Intervention studies trailing different techniques would be beneficial to create concrete guidelines for team supervisors on the best way to discuss incidents.

5.4.5 Summary

Chapter 5 has addressed RQ1, relating to how networks are used in LFI. This research question is a clear gap in the literature than has been identified in two literature reviews (Drupsteen & Guldenmund, 2014; Lindberg et al., 2010). The analysis presented in this chapter has both quantitatively explored the network structure and characteristics, and qualitatively delved into how those structures are used. Nonetheless, the results presented here are descriptive in nature: SNA is a useful toolkit for describing structure and purpose of networks, but lacks the ability to place networks in a cultural context to understand why they matter (Emirbayer & Goodwin, 1994).

Chapter 6 will begin to address the limitations of this chapter by unpacking the most important aspect of a workplace context: perceived objectives (Engeström & Sannino, 2010). Without understanding what workers understand by successful learning in LFI, and thus its objectives, it is impossible to comment on how networks are being used to achieve these goals.
Chapter 7 will further address this limitation of SNA by complementing the results of Chapter 6 with a description of other aspects of the cultural historical activity system.
Chapter 6 explores what workers perceive as successful learning in the context of learning from incidents (LFI). As described in Sections 3.5 and 4.5, activity theory is a central pillar of the theoretical framework used in this thesis. In activity theory, the objectives that a community strives towards are understood to be the driving force of actions (Engeström, 2014), which was explained in greater detail in Section 3.5. In order to place the understanding of networks described in Chapter 5 in context using activity theory, it is therefore of vital importance to fully understand what successful learning entails and consequently what subjects perceive as their learning objectives. The perceived learning objectives of the (LFI) process will subsequently dictate how workers engage with incident-information. The thematic analysis in this chapter hence addresses the research question:

**RQ2a:** What do workers perceive as successful learning in the context of LFI?

Additionally, in order to facilitate activity theory which will be used to investigate RQ3a and RQ3b, the views of managerial and front-line workers were compared to establish the number of activity systems present in each case.

Figure 25 shows how the analysis in this chapter fits within the broader design of the thesis and case studies.

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6.1 Introduction

In activity theory a distinction is made between objectives and outcomes (Engeström, 1999b). From the LFI literature it is clear that the desired outcome of the LFI process is a reduced number of incidents, and that this outcome is accomplished by successfully achieving the objective of learning from previous events (Drupsteen & Guldenmund, 2014; Lindberg et al., 2010). However, definitions of learning vary widely from those oriented towards changes in individual behaviour (Skinner, 1963), to those concerned with knowledge embedded in collective tasks and routines (Paavola et al., 2004; Sfard, 1998). Furthermore, learning in organisations can be considered as both a process and a product (Argyris & Schön, 1996). What successful learning entails in the context of LFI, as either a product or a process, is still poorly defined and in need of exploration (Margaryan et al., 2017). High-risk industries invest large amounts of resources into the LFI
process, but without clearly defined objectives it may be difficult for organisations to assess how successfully they are learning.

In order to explore the perceptions of learning that participants held in the context of LFI a thematic analysis was conducted to produce a taxonomy of learning objectives. In other words, in Chapter 6 I will provide a detailed breakdown of the various components of what people perceive as learning in the LFI process. For example, from the literature it can be understood that part of learning in the LFI process involves the creation of quality reports for others to read (Jacobsson et al., 2012), but may also involve changes to organisational procedures (Tamuz et al., 2011). The production of a taxonomy of learning objectives is a necessary step to further the conceptualisation of LFI in general (Margaryan et al., 2017). A detailed understanding of perceived objectives is also essential when conducting any activity theory based analysis (Postholm, 2015).

Of further interest is whether workers in an organisation have a joint understanding of the objectives of the LFI process, or whether they vary from person to person, or from group to group. Those within an activity system are considered to have common objectives (Nardi, 1996). Nonetheless, an activity system is comprised of multiple individuals who each have their own understanding of the purpose of tasks (Engeström, 2001). A large diversity of views on objectives within an activity system, or between two interacting activity systems, such as management and front-line workers, is a potential contradiction (Engeström, 2014). The taxonomy of learning objectives was therefore used as a base on which to understand the diversity of views present within different groups in the case studies.

6.2 Methods

6.2.1 Settings and Participants

Full descriptions of the context of each of the three organisations that took part in this thesis can be found in Section 4.9. The following section presents an overview of the participants who took part in the interviews that were central to this chapter’s analysis. The interview data presented in this chapter are from the same participants whose answers were used in analysis in Chapter 5, and will be used for analysis in Chapter 7. While the data used in Chapter 6 is the same as some of the data used in Chapter 5, the analysis in Chapter 6 investigates a different aspect of LFI. Chapter 5 focused on creating a description of the experiences of participants with networks, while Chapter 6’s analysis explores what participants viewed as their objectives when using networks, or during other LFI related activities. As detailed in Section 4.9, the interview script was carefully designed to ensure that the interview transcripts would be able to produce data for four different
analysis approaches: qualitative social network analysis, thematic analysis, creation of activity system descriptions, and identification of discursive manifestations of contradictions.

Participants from Company B came from four teams of engineers. 11 participants were interviewed from Company B. Nine of the participants were from front-line positions, and two from managerial roles. All interviews were conducted via Skype. 16 workers from Company C participated in interviews. All participants were involved in production. 10 participants were front-line workers, while six possessed managerial positions. 12 of the interviews were conducted in person, while six were held on Skype. A reminder of the participants is presented in Table 20.

<table>
<thead>
<tr>
<th>Company</th>
<th>Job type</th>
<th>Number of participants</th>
</tr>
</thead>
<tbody>
<tr>
<td>B</td>
<td>Engineering front-line</td>
<td>9</td>
</tr>
<tr>
<td>B</td>
<td>Engineering management</td>
<td>2</td>
</tr>
<tr>
<td>C</td>
<td>Production front-line</td>
<td>10</td>
</tr>
<tr>
<td>C</td>
<td>Production management</td>
<td>6</td>
</tr>
<tr>
<td>Total</td>
<td>Front-line</td>
<td>27</td>
</tr>
<tr>
<td>Total</td>
<td>Management</td>
<td>18</td>
</tr>
<tr>
<td>Total</td>
<td>All</td>
<td>45</td>
</tr>
</tbody>
</table>

6.2.2 Qualitative Instrument

The interview script can be seen in full in Appendix 2. Three interview questions were designed to explore what participants perceived as the objectives of LFI. Prior to undertaking an interview, participants were asked to complete two quantitative instruments. As the interface of the questionnaire distribution platform, JISC Online Surveys, presented the two instruments as a single survey for ease of completion, an additional open-ended question was added. The open-ended question asked “please tell us about a recent time when you found safety information useful. How did you use this information to make your work safer?” The answer to this question was used as a starting point for the interview, where participants were asked to expand upon their answer, prompted to provide details of where they obtained the safety information, and specify any connection between the safety information they described and incidents. Asking participants to provide an example while completing their initial surveys decreased the likelihood that participants would be unable to provide an example when put under pressure during the interview.
In the second question designed to explore learning objectives, participants discussed a major incident that had occurred at their organisation and their organisation’s response. In Company C the gatekeeper at each organisation was able to provide a large scale incident that participants would be familiar with. Each incident had occurred approximately five years prior to the time of the interviews, and resulted in several organisational changes that the researcher was made familiar with. The gatekeeper at Company B was unable to provide an incident that would be applicable to all interview participants, as incident-information was targeted on a geographical basis. Instead the researcher asked participants to think of the largest incident that they could recall during the last 10 years at Company B. After a suitable example had been elicited, the researcher then asked the participant to describe the incident in detail. Regardless of whether the participant was provided with a major incident or asked to recall one, the follow up sub-questions asked the participant to describe how their own work had changed following the incident, what changes the organisation made in general, and finally if there were any additional changes that the participant thought should have been made.

As the final question of the interview participants were asked what they perceived as the purpose of distributing information on incidents. Two sub-questions were asked following the participants’ answers, asking them to describe how a worker who learnt well would conduct their work differently, and how the organisation could know if workers were learning well.

6.2.3 Thematic Analysis

Operationalising learning

As mentioned in Chapter 2, learning has been operationalised in several ways in the literature on LFI. It has been conceptualised as, for example, the organisational changes that have resulted from incident investigations (Stackhouse & Stewart, 2017), the process through which individuals learn (Koehn et al., 2016), or the number of incident reports submitted (Leroy et al., 2012). Learning during the LFI process can therefore be considered in a variety of ways. As shall be discussed below, codes in the thematic analysis were inductively generated (Strauss & Corbin, 1998). However, before generating codes it was necessary to have a clearer understanding of what learning might encompass, as learning has been used in such a variety of ways not just in literature related to the LFI process, but across the discipline of education in general (Paavola et al., 2004; Sfard, 1998).

In this thesis learning was considered in line with Argyris and Schön’s (1996) proposition that it is both a product and a process. This proposition conceptualises learning both in terms of
what are outcomes that should be produced, and what is necessary in order for an effective process that may lead to changes in behaviour (Driscoll, 2000).

**Inductive generation of learning taxonomy**

An inductive method (Strauss & Corbin, 1998) was used to generate a taxonomy of different learning objectives. Building on the operationalisation of learning, an objective was taken to be either a desired change resulting from the LFI process, or a necessity for effective learning during the LFI process. The analysis procedure followed the six step iterative procedure of thematic analysis: familiarisation of the data, generating initial codes, searching for themes, reviewing themes, defining and naming themes, and producing the report (Braun & Clarke, 2006; Braun et al., 2019; Nowell, Norris, White, & Moules, 2017).

Initially the creation of codes was undertaken using only the data from Company A. First, in line with Braun et al. (2019), I became familiar with the interview data through re-listening to interviews, transcribing the audio data, and re-reading the transcripts. Notes taken during the interview process were also re-read. Initial codes were then generated: after becoming familiar with the data I read through the transcripts and noted any concepts that were associated with learning. These concepts were used as initial codes and applied to the interview transcripts to compare how well initial ideas matched the data on a detailed level. The codes were then updated to better reflect the data and reduce redundancy.

Mind-maps were drawn in order to better visualise and reflect on potential connections between codes and create over-arching themes, as suggested by Braun and Clarke (2006). A table was created with detailed descriptions of each code within their over-arching themes. I then applied the codes to all interview transcripts [redacted]. I then shared one interview transcript with one of my supervisors and discussed which codes were relevant to each paragraph within the interview transcript. Following the discussion several code definitions were updated, some codes were merged, and some codes were added. A different interview was then selected and I discussed it with a third independent researcher. The codes and definitions were once again updated. This initial coding scheme is displayed as a mind-map in Figure 26.
The initial themes, codes, sub-codes, and descriptions were presented to [redacted] my industrial supervisors. After discussion it became clear that themes with a stronger theoretical link to learning would be beneficial for practitioners. Tynjälä’s (2013) 3-P model of workplace learning (see Section 3.7) was thus used deductively to collect codes into themes. The 3-P model of workplace learning was chosen due to its close alignment to the notion of learning as both a product and a process, a key component to operationalising learning in this thesis (Murphy et al., 2018a). In addition, the original 3-P model of learning was developed as a way to summarise multiple models of learning in a manner that practitioners could engage with (Biggs, 1993). As the results of this thesis aim to be of use to a non-academic audience, this strength of the 3-P model seemed appropriate for the analysis. In order to make the language of the model more accessible the ‘presage’ theme was divided into two: ‘learner characteristics’ and ‘learning environment’. The modified version of the 3-P model of workplace learning is shown in Figure 27. The thematic analysis therefore incorporated a hybrid approach, utilising both inductive and deductive methods (Swain, 2018).
This process was then repeated with the data from Company C. The codes and themes described above became the initial coding scheme which I compared to the data in order to assess its suitability. The same two additional researchers were once again provided with access to an interview script each from Company C. On a paragraph by paragraph basis the suitability of the coding scheme was discussed and updated. Finally, the codes were applied to the transcripts of participants from Company B. No more changes were deemed necessary to the taxonomy after application to the data from Company B.

6.2.4 Comparison Between Groups
Magnitude coding was carried out to enable comparison between participants. Magnitude coding entails applying a code that can indicate strength, frequency, presence or direction of a concept (Saldaña, 2016). In this analysis the presence or absence of a code was noted against each interview transcript. The number of times each code was applied in each interview could have been used as the basis for comparison (Hsieh & Shannon, 2005), however I deemed that approach to have questionable validity. Interview responses are heavily dependent upon the questions asked (Gubrium & Holstein, 2002). As responses to all questions in the interview were included in the thematic analysis, including those not specifically designed to prompt examples of effective
learning, some codes were applied a disproportionate amount of time. In the analysis this validity issue was relevant for codes related to communication, as responses to the questions in the interview that enabled Chapter 5’s social network analysis caused communication related codes to be applied a multitude of times. For example, ‘formal communication pathways’ was applied 670 times compared to the 84 times that the code ‘improved risk knowledge’ was applied.

Initial comparison was undertaken through statistical analysis of the proportion of the front-line workers who mentioned a code versus the proportion of management who mentioned a code. While a chi-squared test is usually used to compare two distributions of count data, this approach was inappropriate due to the low frequency of the counts. Fisher’s exact test was therefore employed, which is more accurate for low frequency counts (Fisher, 1922). Qualitative observations were also made about the frequency of codes.

6.3 Findings
6.3.1 Taxonomy of Learning Objectives
The final coding scheme derived is shown in Figure 28 and Table 21. The themes ‘process’, ‘learner characteristics’, and ‘learning environment’ predominantly addressed learning as a process, describing objectives that were necessary in order for learning to occur. The ‘product’ theme detailed nine desired learning products that could lead to a reduction in the number of incidents.
Figure 28 Results mapped onto the 3P model of workplace learning
<table>
<thead>
<tr>
<th>Theme</th>
<th>Code</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Learning Environment</td>
<td>Transparency</td>
<td>Information and decision making rationale are available to all workers</td>
</tr>
<tr>
<td></td>
<td>Formal communication pathways</td>
<td>The organisation has sufficient communication channels to allow targeted incident-information to be exchanged</td>
</tr>
<tr>
<td></td>
<td>Impromptu communication</td>
<td>Workers regularly communicate in an unstructured way about incidents</td>
</tr>
<tr>
<td></td>
<td>Safety as an organisational value</td>
<td>Safety is at the forefront of everything that the organisation does, and its internal structures reflect that</td>
</tr>
<tr>
<td></td>
<td>Company strategy reacts to incidents</td>
<td>The organisation uses information on incidents to inform its strategies and priorities</td>
</tr>
<tr>
<td></td>
<td>Organisational memory</td>
<td>Incident-information is integrated into organisational memory to prevent future incidents after a workforce turnover.</td>
</tr>
<tr>
<td>Learner characteristics</td>
<td>Motivation to learn</td>
<td>Workers show a willingness to improve themselves and the organisation</td>
</tr>
<tr>
<td></td>
<td>Locative knowledge</td>
<td>Workers know where to find incident-related information</td>
</tr>
<tr>
<td></td>
<td>Risk perception</td>
<td>Workers have an accurate perception of how dangerous a particular task is</td>
</tr>
<tr>
<td></td>
<td>Safety mindset</td>
<td>Safety is at the first priority of workers</td>
</tr>
<tr>
<td>Process</td>
<td>Communication openness</td>
<td>Workers at all levels are able to openly engage in two-way communication both within and between groups</td>
</tr>
<tr>
<td></td>
<td>Information quality</td>
<td>The information that workers receive on incidents is high quality</td>
</tr>
<tr>
<td></td>
<td>Evaluation</td>
<td>Changes are evaluated after they have been made in response to an incident</td>
</tr>
<tr>
<td></td>
<td>Monitoring</td>
<td>Data is collected and analysed on daily safety practices, incidents and learning</td>
</tr>
<tr>
<td>Impactful delivery</td>
<td>Incident-information intended is delivered in a way that is effective and relevant to tasks carried out by workers</td>
<td></td>
</tr>
<tr>
<td>--------------------</td>
<td>--------------------------------------------------------------------------------------------------</td>
<td></td>
</tr>
<tr>
<td>Product</td>
<td>Updated best practice</td>
<td>Unofficial changes to how tasks are carried out</td>
</tr>
<tr>
<td></td>
<td>Updated official procedures</td>
<td>Updates to the official way in which tasks are carried out</td>
</tr>
<tr>
<td></td>
<td>Updated technology</td>
<td>New technology is introduced to do the same task</td>
</tr>
<tr>
<td></td>
<td>Additional safety barriers</td>
<td>An extra layer of safety is added to a procedure, e.g., a new type of personal protective equipment is used</td>
</tr>
<tr>
<td></td>
<td>Improved procedural knowledge and skills</td>
<td>Workers have deeper knowledge of processes, including reasons behind approaches</td>
</tr>
<tr>
<td></td>
<td>Improved risk knowledge</td>
<td>Workers have more knowledge of particular hazards, e.g., chemicals</td>
</tr>
<tr>
<td></td>
<td>No repeated incidents</td>
<td>No accidents occur due to a known risk</td>
</tr>
<tr>
<td></td>
<td>Fewer incidents</td>
<td>The overall number of accidents and near-misses is reduced</td>
</tr>
<tr>
<td></td>
<td>Incident report numbers changing</td>
<td>The number of reports on incidents either increases or decreases</td>
</tr>
</tbody>
</table>
The proportion of participants in each organisation who mentioned each code is displayed in Figure 29, split between management and front-line groups.

[redacted]

*Figure 29 Heat-map of codes mentioned by participants in each group*

**Learning environment**

Table 22 provides a count of the number of participants who mentioned each of the objectives related to the learning environment. Codes related to communication, in other words ‘formal communication pathways’ and ‘impromptu communication’, were the most common codes used for learning objectives across the interviews; ‘formal communication pathways’ were mentioned by all participants, and ‘impromptu communication’ was mentioned by all but two. As observed in the method section of this chapter, the prevalence of these themes could be due to the fact that several questions in the interview related to the networks of participants. Furthermore, the entire topic of this thesis relates to the latter half of the LFI process, when information is received about an incident in which workers were usually not involved. For workers to learn incident-information must be communicated to the worker through either a formal or informal means. Nevertheless, the high frequency of these codes is consistent with the importance of communication noted in two literature reviews on LFI (Drupsteen & Guldenmund, 2014; Lindberg et al., 2010).

Apart from the objectives related to communication, most participants also mentioned ‘safety as an organisational value’ as a learning objective. There was no evidence of the other three learning objectives in the majority of the responses provided by participants. Nevertheless, examples of ‘organisational memory’ and ‘company strategy reacts to incidents’ being necessary to support learning were provided by at least 40% of participants.

*Table 22 Count of participants who mentioned each learning environment objective*

<table>
<thead>
<tr>
<th>Learning Objective</th>
<th>Total participants who mentioned code</th>
<th>Percentage participants who mentioned code</th>
</tr>
</thead>
<tbody>
<tr>
<td>Formal communication pathways</td>
<td>45</td>
<td>100.0%</td>
</tr>
<tr>
<td>Impromptu communication</td>
<td>43</td>
<td>95.6%</td>
</tr>
<tr>
<td>Safety as an organisational value</td>
<td>31</td>
<td>68.9%</td>
</tr>
<tr>
<td>Organisational memory</td>
<td>19</td>
<td>42.2%</td>
</tr>
</tbody>
</table>
One aspect of communication that became apparent during the thematic analysis was the fundamental need for having established and structured formal pathways through which incident-information was distributed. [redacted]. In contrast, all other participants [redacted] felt that there were many established ways in which incident-information was communicated formally, as their roles made them primary recipients of incident-information.

Despite the need for formal pathways that provided relevant workers with incident-information, flexibility was also seen as vital in incident-information communication, particularly by those in managerial roles. When front-line workers at Company C were asked who they would approach if they had a safety related concern their answer was usually their closest colleagues. In Company B all front-line workers said they would approach their safety assurance engineer first. However, for those in managerial roles their response was usually that it would depend on the nature of the safety concern and how it would relate to an incident. Participant B7, a manager, described how he would ask the safety assurance engineer if there was uncertainty over best practice, his manager or the manager of the safety team if he felt there was an issue with a procedure, or one of his team if he was worried that there was a technical misunderstanding in multiple engineers. This difference in approach between organisations and roles highlighted that there are multiple ways the learning objectives of LFI can be achieved, depending upon the nature of the workplace.

Leadership and company strategy was another topic that emerged during interviews. Participants felt that company strategy, mainly resource allocation, should be influenced by incidents. [redacted]. Another example of resource allocation was provided by Participant C8, a manager, who described how every month members of the production management team sat down and reviewed incidents to decide what was relevant for their units, and what responses should be prioritised.

Leadership’s behaviour was also important in demonstrating that safety was valued highly within each organisation. One participant retailed the difference he had felt in the organisation attitude to safety since a new head of their department had begun his position:

‘He’s like a breath of fresh air. And safety is his number one bi-word. Whereas before it seems to be the production was the number one priority.’
Others noted that the official organisational policies during hiring, performance reviews, and particularly in response to incidents all set the tone for whether safety and learning or production and attractive metrics were prioritised. Closely linked to this aspect of learning was another environmental factor: transparency. Transparency was most directly raised in relation to the legal team removing information from incident alerts that could be beneficial to workers. However, transparency was also raised in relation to the reasons for decisions being clear. For example, Participant B3, a front-line worker, described an experience where engineers were required to replace a piece of equipment regardless of its condition. From the workers’ perspectives the frequent replacements were unnecessary and introduced additional risks to their work. However, his team supervisor was able to explain that it was necessary due to propriety issues, and it was an ongoing problem that the leadership were working towards finding a solution for. While everyone involved knew that it was not the ideal situation, Participant B3 described how workers were willing to accept the sub-optimal procedure because of the transparency of the reasoning and continued efforts to eliminate the risk.

The final learning objective code that emerged from analysis was ‘organisational memory’. The LFI process is depicted in literature as a procedure that initially takes the input of an incident report and results in the reduction of incidents (Stemn et al., 2018). While an incident is often the initial input in this process, LFI is far from a linear process with one incident leading to clear cut improvements that reduce incidents (Lundberg et al., 2009, 2010; Tamuz et al., 2011). Incidents are often embedded in organisational tools, such as training materials or procedures, with the aim of educating people continuously about risks. In this way new recruits, or even other organisations, can learn from an incident at any point in the future (Jacobsson et al., 2009, 2010). For example, Participant C8, a manager who was involved with the orientation of new workers, described how incidents were embedded in the training for new-hires:

‘So there’s a number of different learnings that we get from that specific [other company] incident that we share. But then we also explained how from that incident we then implemented change in our documentation, because we saw that as a potential for in our systems. And so then we developed a program that would make sure that if we face that situation we would deal with it, with good documentation.’

Participant C8, Management
Learner characteristics

Table 23 shows the number of participants who mentioned each of the learning objectives related to learner characteristics. Unlike the learning environment theme, there were no objectives mentioned by all participants. Nevertheless, there was evidence that participants considered ‘safety mindset’, ‘risk perception’, and ‘locative knowledge’ as important for supporting the learning process. ‘Motivation to learn’, on the other hand, was one of the least frequent learning objectives mentioned in any of the organisations.

<table>
<thead>
<tr>
<th>Learning Objective</th>
<th>Total participants who mentioned code</th>
<th>Percentage participants who mentioned code</th>
</tr>
</thead>
<tbody>
<tr>
<td>Safety mindset</td>
<td>37</td>
<td>82.2%</td>
</tr>
<tr>
<td>Risk perception</td>
<td>30</td>
<td>66.7%</td>
</tr>
<tr>
<td>Locative knowledge</td>
<td>22</td>
<td>48.9%</td>
</tr>
<tr>
<td>Motivation to learn</td>
<td>6</td>
<td>13.3%</td>
</tr>
</tbody>
</table>

Two of the codes related to learner characteristics concerned the attitudes and perceptions of danger that participants experienced. When asked about what changes a worker should display after receiving information, a common perception was that changes were not necessary after receiving the majority of information on incidents. 12 participants saw the distribution of incident-information as part of reminding workers to have a safety-oriented mindset, without actually changing their working routines:

‘It’s more just opened your eyes, just make sure you’re being safe. I mean touch wood I’ve never had any accidents or anything, but yeah it does open your eyes to just take your time’

*Participant B4, Front-line*

However, besides seeing the incident alerts as part of developing a general safety-related focus to their work, participants also specifically understood incident alerts as a way of reminding them of exactly how dangerous their work could be. Working in a dangerous environment everyday meant
that risks could become normalised, and no longer treated with adequate respect due to inaccurate perceptions of risk levels (Hovden et al., 2011). Being reminded of the consequences of incidents was seen as a way to combat risk normalisation:

‘I think if a massive incident happened somewhere in the world today, and then we all got to find out about it, it would make everybody stand back for about 5 minutes and think about what they were doing... But over a period of time he gets forgotten about the, it gets relaxed doesn’t it? Everything goes back to normal.’

Participant C14, Front-line

One area that was mentioned consistently across the three organisations was the ability to find and locate knowledge. This ability closely aligns to the locative knowledge aspect of Lukic et al.'s (2012) LFI framework, i.e., the knowledge of where to find information when needed. Nevertheless, there was disparity between the three organisations as to how they would find information, either about an incident or to contextualise an incident and understand its relevance. Chapter 5 and Chapter 7 describe in detail the various methods of locating knowledge employed in the different organisations; however, they can be summarised as immediate colleagues, colleagues with specialised knowledge, incident reporting systems, records of work history, and databases of information on risks, such as chemicals. Locative knowledge was spoken about most explicitly by Participant B9, a front-line worker who was the designated coach for his team. Due to his role other team members would frequently contact him with technical questions or safety concerns. Despite knowing the answer to most questions Participant B9 would usually not directly tell the engineer what they were seeking to know, rather direct them to where they can find that information. He commented, ‘it’s all well and good me going that’s the answer, but they need to find out why it is a risk’.

One of the most infrequently applied codes was ‘motivation to learn’, despite being acknowledged in the literature as a key part of both learning and safety culture (Littlejohn, Lukic, & Margaryan, 2014). [redacted]. Participant C11, a relatively inexperienced front-line worker, noted that Company C seemed to provide incentives for people to proactively learn and adapt their work. The remaining four participants who mentioned motivation to learn all did so by observing that more experienced workers were often resistant to changes that resulted from incidents, only wanting to update their established work practice if they saw a good reason for it. While ‘motivation to learn’ was mentioned relatively infrequently by participants it was highly
valued by those who did discuss it. Combined with its relevance in the LFI literature it is likely that the count of the number of participants who mentioned the objective does not adequately reflect its importance, as without motivated workers no learning is likely to occur regardless of the quality of the learning process.

**Process**

Table 24 shows the number of participants who mentioned each learning objective related to the process of learning. As with learner characteristics, all but one of the objectives in this theme were mentioned by over 45% of participants. However, evaluation of the changes that resulted from LFI as necessary for an effective learning process was mentioned by only 20.0% of participants.

<table>
<thead>
<tr>
<th>Learning Objective</th>
<th>Total participants who mentioned code</th>
<th>Percentage participants who mentioned code</th>
</tr>
</thead>
<tbody>
<tr>
<td>Monitoring</td>
<td>36</td>
<td>80.0%</td>
</tr>
<tr>
<td>Communication openness</td>
<td>32</td>
<td>71.1%</td>
</tr>
<tr>
<td>Impactful delivery</td>
<td>30</td>
<td>66.7%</td>
</tr>
<tr>
<td>Information quality</td>
<td>21</td>
<td>46.7%</td>
</tr>
<tr>
<td>Evaluation</td>
<td>9</td>
<td>20.0%</td>
</tr>
</tbody>
</table>

At all three organisations, as was discussed in Chapter 5, the main ways of receiving and engaging with incident-information were emails and team meetings. This finding was reiterated in what participants described as necessary for an effective learning process. Open communication was a priority for the front-line workers at all three organisations, which participants saw as vital to enable learning. This observation agrees with one of the components that Littlejohn et al.’s (2014) literature review identified as central to both learning and safety cultures. Additionally, communication openness has a strong connection to psychological safety, which has been shown to have a significant influence on team learning (Edmondson, 1999).

In addition, two other codes closely related to the way in which information was received. One distinction that was made by several participants was that they felt meetings were more impactful than emails.
Other participants mentioned that discussion during team meetings created opportunities to exchange ideas, and made team meetings a more impactful form of delivery.

The quality of information contained in incident reports was also seen as important, [redacted] seven participants from Company C commenting either that it needed to be concise enough to be readable, or that the information needed to pertain to an incident that was seen as relevant:

‘Which, like I say, can be multiple pages of information which people aren't going to read and they'll miss the point that they're trying to get to. So that's the biggest thing is just purely readability.’

Participant C1, Management

Participant B2, a front-line worker, was the only participant in his organisation to mention that information needed to be relevant, providing an example of an incident report that he had found meaningless because its recommendations seemed like common sense.

The final two codes in the process theme related not to how individuals received information, but to the ongoing LFI process. The need to evaluate actions put in place as a result of incident investigations was only discussed by nine participants [redacted]. Those who did mention the need to evaluate actions were very adamant about its value:

In the two published models of the LFI process only one, Drupsteen et al.’s (2013), included an evaluation step. Although relatively few participants in this thesis spoke about the need to evaluate changes as a part of the LFI process, the significance of the step as perceived by those who mentioned it presents an argument for its inclusion.

Continuous monitoring of production processes was, conversely, mentioned by 36 of the 45 participants. Rather than this monitoring being to evaluate change resulting from incidents,
participants stated the importance of trying to predict what kinds of incidents could occur in the future based on data provided by frequent audits and examining incident trends.

**Product**

Table 25 displays the number of participants who mentioned each learning objective related to the desired products that should result from LFI. Most participants agreed that LFI should result in changing the way that work is conducted, either through an update in best practice, procedures, or additional safety barriers. The majority also provided evidence that they believed the knowledge of a worker, either related to risks or procedures, should be improved. There were also some learning products that were not as commonly mentioned: ‘updated technology’ and ‘incident report numbers changing’.

There were nine products that participants [redacted] described as desired learning objectives. The most commonly described were changes to the way that work tasks were carried out. 34 of the 45 participants mentioned that official procedures should be updated in order to reduce the likelihood of incidents. 37 reported that best practice should be updated. A distinction was often made by participants between the ways that a task was performed ideally, in other words best practice, and the official policy. In the case of the major incident discussed at Company C and the large incidents described by participants in Company B, participants felt that current procedures were sufficient to avoid future incidents, but that the rules needed to be followed closely to be effective. This distinction mirrors the theoretical difference that is made between espoused-theory and theory-in-use in organisational learning literature (Argyris & Schön, 1996; Lukic et al., 2012), see Section 2.3.4. Procedures are a form of embedded knowledge, as insights garnered from previous incidents are used to update procedures and guide workers who read them. However, the reality of how workers conduct tasks can differ from what is described in the procedures. The codes ‘updated technology’ and ‘additional safety barriers’ represented specific examples of this change in work practice, although neither necessarily impacted best practice or official procedures and thus were considered separate codes. Nonetheless, updated best practice and official policy often included extra checks, one form of an additional safety barrier. [redacted].
Table 25 Count of participants who mentioned each product learning objective

<table>
<thead>
<tr>
<th>Learning Objective</th>
<th>Total participants who mentioned code</th>
<th>Percentage participants who mentioned code</th>
</tr>
</thead>
<tbody>
<tr>
<td>Updated best practice</td>
<td>37</td>
<td>82.2%</td>
</tr>
<tr>
<td>Improved risk knowledge</td>
<td>34</td>
<td>75.5%</td>
</tr>
<tr>
<td>Updated procedures</td>
<td>34</td>
<td>75.5%</td>
</tr>
<tr>
<td>Additional safety barriers</td>
<td>33</td>
<td>73.3%</td>
</tr>
<tr>
<td>No repeated incidents</td>
<td>29</td>
<td>64.4%</td>
</tr>
<tr>
<td>Improved procedural knowledge and skills</td>
<td>28</td>
<td>62.2%</td>
</tr>
<tr>
<td>Fewer incidents</td>
<td>19</td>
<td>42.2%</td>
</tr>
<tr>
<td>Updated technology</td>
<td>12</td>
<td>26.7%</td>
</tr>
<tr>
<td>Incident report numbers changing</td>
<td>5</td>
<td>11.1%</td>
</tr>
</tbody>
</table>

Besides changes to the way that tasks were completed, additional objectives related to the underlying knowledge of workers on particular risks and related procedures. In Company C one participant (Participant C10, Front-line) described an incident alert received from another organisation. A drum had been filled with hot oil and opened prematurely. In normal circumstances the oil was cooled using steam followed by water, but in this particular incident only steam had been available so the oil was left an additional five days to cool. In reality it should have been left around three weeks before it was safe to open. The participant commented that he had not been aware of how long it took for oil to lose its heat and would have most likely made the same mistake. His knowledge of the risks of hot oil had increased due to this incident.

Conversely, other participants described a better understanding of the details of procedures and the reasoning behind particular steps. For example, Participant B2, a front-line worker, provided an example of receiving information on how a colleague had handled an incident related to carbon monoxide. The incident was shared in a team meeting as an example of how well his colleague had correctly dealt with the risk. Participant B2 realised that his knowledge of this procedure had been incomplete, and he had in the past, unknowingly, not followed it.

The final kind of product related learning objective code related to metrics. 19 participants stated that a general reduction in the number of incidents was one goal of distributing incident-information. 29 participants asserted that the LFI process should specifically reduce the number of repeated incidents, in other words, incidents with similar underlying causes. Interestingly only 5 participants mentioned changes in the number of incident reports.
submitted as a learning objective, despite this being a frequently used proxy for learning in LFI literature (e.g., J. G. Anderson et al., 2010; Leroy et al., 2012). Participant C11, a front-line worker, responded when asked how organisations can know if they are learning:

‘Obviously if there’s a decrease in [incident reports], and obviously a decrease in near-misses which are recorded on the [incident reporting] system anyway.’

*Participant C11, Front-line*

However, Participant C1 observed:

‘We do put these [incident reports] in quite freely for a warning to others. So if we saw that [incident reporting number] coming down we have to hope it was coming down because people were working safer.’

*Participant C1, Management*

Participant C16 echoed this uncertainty on being able to interpret the amount of incident reports submitted:

‘I suppose if something happened and they don’t want to, nobody wants to tell you about it then you’re going to struggle to get to know about it.’

*Participant C16, Management*

While it is a common measure of learning, it is difficult to know the quality of the data submitted and whether there is missing data in the form of unreported incidents. This is perhaps why so few participants related the number of incident reports submitted as a learning objective, despite reporting incidents being a key step in the LFI process (Drupsteen et al., 2013; Haw et al., 2014).
Summary of taxonomy of learning objectives

Section 6.3.1 presented a taxonomy of learning objectives associated with LFI mapped onto the 3-P model of workplace learning (Tynjälä, 2013). The narrative behind each of the learning objectives was unpacked with examples from the interview data. However, what remains unclear is how closely aligned the views of the managerial and front-line participants were on what they perceived as their goals. This is essential to understand when conducting analysis within an activity theory framework in Chapter 7, as the similarity of views of objectives will define if managerial and front-line participants should be considered as part of the same activity system (Nardi, 1996). Section 6.3.2 will therefore present the results of a statistical analysis to assess whether there was evidence that management and front-line participants should be considered as one or two activity systems.

6.3.2 Comparison Between Groups

For all learning objective codes there was no statistically significant difference between the proportion of managers who mentioned a learning objective and the proportion of front-line workers who mentioned it, as evaluated by a Fisher’s exact test. For this reason, there will be no distinction made between the activity systems of managers and front-line workers in Chapter 7’s activity theory analysis when addressing RQ3a and RQ3b.

From examination of the heat map in Figure 29, there appeared to be several codes that were seen by participants across organisations and job roles as important. Where there was a difference, albeit not a statistically significant one, potential explanations could be found through consideration of work context. For example, ‘communication openness’ was mentioned [redacted] by a larger proportion of front-line employees than management. Similar to the findings of Lukic et al. (2013), participants described experiences of times when they had felt empowered to voices their opinions and thoughts, but also incidents where a lack of feedback on their ideas had discouraged future contributions. Management, on the other hand, were usually a part of the decision-making process or able to pass their ideas on to people with the power to directly act upon suggestions.

On the contrary, ‘company strategy reacting to incidents’ was a learning objective from the learning environment theme that managerial participants [redacted] were more likely to mention during their interview than their front-line counterparts. As their jobs focused on the creation and execution of over-arching strategies for their department, this objective was likely to be one that related the responsibilities of management, but not those on the front-line. In addition, for managerial participants the company strategy considering incident trends would
dictate the resources available to them, subsequently dictating their learning environment when engaging in LFI. Experiences, such as those related to ‘communication openness’, are likely to inform the learning objectives of workers, but another potential influencer is the aim of a participants’ role.

Another example where work context influenced perceptions of LFI learning objectives was the high proportion of Company B participants who mentioned ‘locative knowledge’. Due to the distributed nature of their work participants were not able to quickly ask a nearby colleague for advice. When questions arose, or more information on a topic was needed, participants needed to contact a particular colleague by phone. Formal titles such as ‘coach’ or ‘safety assurance engineer’ were therefore important signifiers as to who would possess the information they sought as the title was accompanied by an expectation of particular knowledge and responsibilities. In addition, before each task they were provided with the pertinent information by a digital platform. This made the location of applicable material extremely simple and explicit.

While management appeared to agree often with front-line employees within an organisation, or even between groups in different organisations, the number of codes related to learning objectives developed through this thematic analysis speaks to a relatively large diversity of views within each group. From an activity theory perspective this could be seen as a contradiction (Engeström, 2014). However, as there appears to be agreement on a majority of the codes, it is likely that this is more an expression of the natural diversity of opinions than a real issue in the LFI activity system (Engeström, 2001).

### 6.4 Discussion

This chapter outlined the findings from a thematic analysis in order to address RQ2. The analysis explored participants’ perceptions of successful learning in the context of LFI, inductively generating codes that were either desirable products of learning or necessary for a learning process to occur. The inductive codes were then deductively assigned to themes based on the 3-P model of workplace learning (Tynjälä, 2013): product, process, learner characteristics, learning environment. Each code was considered a learning objective of LFI. Finally, in preparation for the activity theory analysis in Chapter 7 a statistical analysis compared whether front-line and managerial workers had different perceptions of the objectives of LFI. No significant evidence was found to support a different between the two groups in any of the organisations.
6.4.1 Objectives Related to Learner Characteristics

Several studies have discussed some of the learning objectives that have emerged from the analysis described in this chapter (e.g., Leicher et al., 2013; Lukic et al., 2013; Rossignol, 2015). Of the four objectives related to ‘learner characteristics’ three have been well established in previous literature on LFI. The objective ‘motivation to learn’ has a strong connection to whether an incident is perceived as a chance to learn, which has been discussed in several studies on LFI (Bauer & Mulder, 2011; Leicher et al., 2013; Rossignol, 2015). Equally, ‘motivation to learn’ could be linked to how much agency a worker feels they have to contribute to LFI (Lukic et al., 2013). The ‘locative knowledge’ objective from the taxonomy, i.e., knowledge on where to find relevant resources, on the other hand, has been mentioned relatively sparsely in research on LFI. It was nonetheless discussed by Lukic et al.’s (2012, 2010) framework as a type of knowledge that should be generated during the LFI process. In the taxonomy of learning objectives generated in this chapter ‘locative knowledge’ was considered a characteristic of the learner because, as described in Chapter 5’s analysis, participants often needed to locate additional information in order to contextualise incident alerts. However, it could be considered also as a desirable product of LFI.

‘Risk perception’ was the third learning objective related to learner characteristics that had been discussed previously in the literature. However, previous studies on this topic have predominantly discussed the concept of accurately assessing levels of risk in relation to reporting an incident. For example, Gilbey et al. (2016) examined through vignettes the likelihood of reporting incidents and found that participants’ decision to report an incident was highly influenced by the actual outcome rather than the potential outcome. The participants in this thesis added an additional dimension to this factor, as risks were described as becoming normalised over time. The ability to understand how dangerous the outcome of an incident could have been is not just linked to decisions to report, however, as this will also impact how workers connect an incident alert to their own work practice (Weick et al., 2005). If an incident is incorrectly seen as being of little consequence, then workers are unlikely to engage with that incident alert.

The fourth learning objective, ‘safety mindset’ has, to the author’s knowledge, not been discussed as an important individual factor in relation to LFI. As safety and learning are complementary in many regards but differ in some respects (Littlejohn et al., 2014), further research is required to understand how a safety-oriented mindset impacts LFI. While the taxonomy has summarised many of the individual factors that affect LFI, one interesting omission was emotions. Other researchers have suggested that the emotional strain associated with incidents has an effect on how workers subsequently learn (Bauer & Mulder, 2011; Catino & Patriotta, 2013; Koehn et al., 2016). While learning vicariously through the incidents of others is
unlikely to generate as strong an emotional response as directly experiencing an incident, the
emotional state of a learner has been shown to affect subsequent learning behaviour (Watzek &
Mulder, 2019). More explicit consideration of emotions could therefore be of benefit to the
taxonomy.

6.4.2 Objectives Related to Learning Environment

The learning environment theme contained six objectives in the taxonomy: ‘formal
communication pathways’, ‘impromptu communication’, ‘safety as an organisational value’,
‘organisational memory’, ‘company strategy reacts to incidents’, and ‘transparency’. Several
researchers have noted the importance of informal learning to complement the more formal
aspects of LFI (Bauer & Mulder, 2007; Gartmeier et al., 2017; Gressgård & Hansen, 2015; Lukic et
al., 2012). Organisations possessing pathways through which to send incident-alerts which are
supplemented by less structured spontaneous interactions fits well within these notions of formal
and informal learning both playing a part in LFI. Other literature on LFI has described how workers
learn through performing their job with others, which would also require impromptu
communication (Braut & Njå, 2013; Rossignol, 2015; Sanne, 2012; Silva et al., 2017; Vastveit et al.,
2015).

The concept of ‘organisational memory’ was used by Jacobsson et al. (2012) in their rubric
to assess the quality of recommendations contained in incident reports but has not been
mentioned by other authors. Despite this relative lack of focus in research conceptualisations of
LFI, embedding knowledge in organisational memory was discussed by several participants as vital
to ensure that insights were embedded in practice and the organisation would not become
vulnerable when new employees started working at the site. ‘Transparency’ in relation to
decisions and information quality has been discussed sparingly in literature on LFI. However,
transparency is a core component of psychological safety, which, as discussed in Section 2.3.2, is
closely linked to whether incidents are discussed and how workers make sense of incident alerts
(Catino & Patriotta, 2013; Edmondson, 2004; Leroy et al., 2012). While ‘communication openness’
was an objective grouped under process in the taxonomy, ‘transparency’ and ‘communication
openness’ are likely to be closely linked, as both are composite elements of psychological safety
(Edmondson & Lei, 2014). Multiple studies have found that the perception of a workplace
environment as open and accepting is related to whether an incident report will be submitted, or
whether an incident will be covered up (Bauer & Mulder, 2011; Leicher et al., 2013; Leroy et al.,
2012). The objective of ‘safety as an organisational value’ has not directly been discussed in the
context of LFI. However, management practices in general have been shown to be important for
LFI, which would be impacted by organisational values (Drach-Zahavy et al., 2014). Management practices have also been associated with psychological safety (Cannon & Edmondson, 2005). As many of the inductively generated categories relate to psychological safety, future iterations of the taxonomy should consider whether this should be condensed into a single objective, or whether it should be split into its different components that influence whether an environment is psychologically safe. One of the advantages to using psychological safety as a single objective is that there is a validated short psychometric survey instrument which has been tested in a variety of environments (Edmondson, 2018).

The final objective, an organisation modifying its priorities and strategies based on incident trends, fits well with the concept of LFI as an organisational cycle of experiential learning. The final two steps of the experiential learning cycle involve updating conceptualisations and testing them (Kolb, 1984). Littlejohn et al. (2017) proposed that changes in procedures would be one desired outcome of LFI. This would be part of the organisation updating its strategies for completing future tasks. However, the concept of updating priorities based on incident trends is novel in the literature on LFI.

### 6.4.3 Objectives Related to Learning Process

The objectives of ‘impactful delivery’ and ‘information quality’ were primarily discussed by participants in relation to the formal LFI activities, such as team meetings. Research on incident-related meetings shows that the effectiveness and impact of such meetings can vary based on a range of considerations, such as facilitator skills and the amount of organisational support provided (J. E. Anderson & Kodate, 2015; Nicolini et al., 2011b, 2011a; Reiter-Palmon et al., 2015). However, this research has primarily focused on incident investigations, rather than discussions that are designed to facilitate learning using an incident-alert. The delivery of incident alerts is undoubtedly an important factor in the learning process; however, much remains unknown about what is beneficial practice in LFI. Participants generally agreed that meetings were more impactful than email, but this remains an area of LFI that needs further attention. ‘Information quality’, on the other hand, has been explored by several groups. Although mainly considering incident reports and records rather than incident alerts, several guidelines on what is considered quality information exist, promoting factors such as sufficient consideration of context (Braut & Njå, 2013) and the number of recommendations provided in each report (J. G. Anderson et al., 2010).

The objectives of ‘monitoring’ and ‘evaluation’ had similarities with the final phase of the LFI process model suggested by Drupsteen et al. (2013). Stackhouse and Stewart (2017) and Lundberg et al. (2010) both found that the recommendations that came from incident-
investigations were highly influenced by what was deemed possible rather than what was necessary to address underlying issues. Returning to the recommendations to ensure that they were, firstly, implemented and, secondly, effective in tackling an issue would be an important way to combat recommendations that only addressed superficial problems. Likewise, monitoring incident trends and how workers perform their work through audits would aid in identifying ineffective changes.

One area for consideration is that, besides ‘communication openness’ which would affect all LFI activities, none of the learning objectives related to process considered what was needed to support informal LFI. As discussed above, several of the objectives related to learner characteristics and learning environment encompassed elements of informal learning. Nonetheless, it is likely that some additional objectives related to informal learning processes could be added to the taxonomy, such as opportunities to observe others performing work (Billett, 2014). The methodology employed in this thesis, however, is unlikely to surface objectives related to informal learning processes, as participants are predisposed to specifically talk about formal opportunities to reflect on incident-information (Simons & Ruijters, 2004).

6.4.4 Objectives Related to Learning Products

The final theme of learning objectives detailed nine products of learning that should result from LFI. Littlejohn et al.’s (2017) model of LFI depicted changes in behaviour or processes as the desired outcome of LFI. These map directly onto ‘updated best practice’ and ‘updated procedures’. ‘Updated technology’ could also be considered in a similar manner as a concrete change, although it would not necessarily impact either the daily practices or procedures of an organisation. ‘No repeated incidents’, ‘fewer incidents’, and ‘incident report numbers changing’ are also widely acknowledged as desirable products of LFI (Le Coze, 2013; Leroy et al., 2012). Although it could be argued that these are outcomes of LFI rather than learning products, they were included in the taxonomy as objectives mentioned by participants. Whether they should be included in a taxonomy of learning objectives should be explored in further research.

The development of different types of knowledge was also discussed by participants. While an increase in knowledge is undoubtedly learning (Paavola et al., 2004; Sfard, 1998), and could lead to a change in behaviour, workers would not necessarily need to modify the way that they conducted their daily tasks. Instead this knowledge could express itself only when encountering unexpected situations, akin to adaptive expertise (Carbonell et al., 2014). This raises issues when considering how organisations can understand if they are learning or not. The taxonomy generated in this chapter could be used as a guide for organisations to evaluate several
factors related to learning. However, measuring adaptive expertise is difficult as it only emerges when required by a difficult situation.

6.5 Limitations

The taxonomy presented in this chapter was created through exploration of what participants considered as good learning. However, as already mentioned in the discussion section, some limitations related to the inclusion of everything mentioned by participants. Several objectives appear to be components of psychological safety, so the number of objectives could potentially be reduced. In contrast, there are likely to be other objectives, such as those related to informal learning processes and emotions, that were not mentioned by participants despite their relevance. Equally it could be debated whether differentiation between ‘fewer incidents’ and ‘no repeated incidents’ is necessary, or whether they should both be considered an outcome of LFI that results from learning, and thus not included. The taxonomy is the first to bring together many of the indicators of learning that have been used in other studies but represents a starting point rather than a complete product.

The largest limitation of the methodology in this chapter, nevertheless, is that all objectives were considered equally important. From the heatmap of responses, Figure 29, it can be seen that some objectives are more ubiquitous than others. However, more important than the prevalence in practitioners’ considerations is their effect on the desired outcome of LFI, reducing the number of incidents. Further research must quantitatively explore which of the 24 objectives in this chapter have the most impact on learning, and subsequently reducing incidents.

6.6 Summary

Chapter 6 related to what workers perceive as successful learning during LFI. The thematic analysis described in this chapter breaks down the many learning objectives that workers associate with the LFI process. Furthermore, the chapter failed to find sufficient evidence to consider management and front-line workers as having differing perspectives on the objectives of LFI. However, how these objectives are accomplished is yet unexplored. Similar to the SNA conducted in Chapter 5, there also remains a connection between these findings and the wider context of the organisations in these case studies. This wider perspective of how the objectives are achieved, and what inhibits their accomplishment, will be explored in Chapter 7.
7 Enablers and Inhibitors of Learning

Chapter 7 unpacks the final stages of analysis undertaken during the thesis. It builds upon both the social network analysis (SNA), described in Chapter 5, and the thematic analysis, undertaken in Chapter 6, to holistically evaluate the learning from incidents (LFI) system at each organisation. It aims to address the following research questions:

RQ3a: What beneficial practices in LFI enable learning?

RQ3b: What barriers to learning exist in the LFI process?

Figure 30 shows how the analysis conducted in this chapter ties into the structure of both the case studies and the thesis.

Figure 30 Analysis conducted in Chapter 7
7.1 Introduction

Activity theory provides a holistic way to conceptualise LFI as a human activity, placing fundamental importance in the historically accumulated contradictions that arise in the LFI activity systems (Engeström, 2001). Overcoming these contradictions is paramount for organisations to make transformative, rather than incremental, improvements (Engeström & Sannino, 2010). While evaluation of different individual aspects can lead to gradual changes, a system must be considered in a holistic manner to allow the assumptions it is based on to be challenged (Argyris & Schön, 1996). By drawing together the previous analyses and employing methodological tools specific to activity theory, the LFI system in each organisation can be examined in relation to how well it can achieve the learning objectives outlined in Chapter 6.

One of the selection criteria of organisations used in this thesis was the requirement to have a mature LFI system in place. The literature on LFI has demonstrated several approaches to learning following an incident that have proven effective, from the use of specific incident investigation techniques (Rollenhagen et al., 2010), to reflective practices within teams (Bauer & Mulder, 2007, 2011). The use of activity theory allows the practices of the three organisations in this thesis to be examined systematically to highlight good practices. While multiple studies have focused on the barriers and difficulties encountered during the LFI process (Dillman et al., 2011; Drupsteen & Hasle, 2014; Haw et al., 2014), insights can equally be drawn from the identification of beneficial practices (Sanne, 2012). As was highlighted in the results of the SNA presented in Chapter 5, each of the organisations which participated in this thesis have unique practices that are beneficial in their own context. While it is unlikely that similar systems can be exactly replicated in other organisations, they form a collection of specific cases that others can draw upon when designing their own LFI systems (Flyvbjerg, 2006). RQ3a therefore aims to describe each organisations’ system for LFI using activity theory, aiming to highlight beneficial practices that enable learning.

Nevertheless, in all complex systems, such as LFI, there will be contradictions that have arisen over the gradual evolution of processes, tools, and communities (Engeström, 2014). While studies to date have examined barriers and inhibitors of learning in the LFI process, most studies have employed methods that provided insights into a relatively narrow aspect of the process. For example, political manoeuvring between different groups within a unit (Tamuz et al., 2011), the low quality recommendations (Lundberg et al., 2010; Stackhouse & Stewart, 2017), and limited time (Drupsteen & Hasle, 2014) have all been found to inhibit learning during the LFI process. However, these issues represent what Argyris and Schön (1996) term as single-loop learning: if resolved they would be an improvement of the same process rather than addressing a
fundamental flaw in the system. While contradictions that can drive transformational
development cannot be directly observed, activity theory provides tools that allow contradictions
to be identified (Engeström & Sannino, 2011). The second aim of this chapter is therefore to
identify contradictions present across the LFI systems of the three organisations that act as
barriers to learning, but, if overcome, could transform LFI.

7.2 Methods
7.2.1 Settings and Participants
Data for this analysis was collected in the same three organisations as the analysis described in
Chapters 5 and 6. Descriptions of the context of each organisation can be found in Section 4.9.

In order to quantitatively evaluate strengths and weaknesses of the LFI process,
participants were requested to complete a survey, the Learning from Incidents Questionnaire
(LFIQ). The LFIQ is a validated instrument specifically designed to gauge different aspects of the
LFI process that should enable effective and sustainable learning (Littlejohn et al., 2017; Margaryan et al., 2018). Table 26 contains a summary of the participants who completed the
LFIQ.

<table>
<thead>
<tr>
<th>Company</th>
<th>Job type</th>
<th>Number of participants invited</th>
<th>Number of respondents</th>
<th>Response rate</th>
</tr>
</thead>
<tbody>
<tr>
<td>B</td>
<td>Front-line</td>
<td>63</td>
<td>47</td>
<td>74.6%</td>
</tr>
<tr>
<td>B</td>
<td>Management</td>
<td>4</td>
<td>0</td>
<td>0.0%</td>
</tr>
<tr>
<td>C</td>
<td>Front-line</td>
<td>104</td>
<td>82</td>
<td>78.8%</td>
</tr>
<tr>
<td>C</td>
<td>Management</td>
<td>4</td>
<td>4</td>
<td>100.0%</td>
</tr>
<tr>
<td>Total</td>
<td>Front-line</td>
<td>213</td>
<td>154</td>
<td>72.3%</td>
</tr>
<tr>
<td>Total</td>
<td>Management</td>
<td>25</td>
<td>11</td>
<td>44.0%</td>
</tr>
<tr>
<td>Total</td>
<td>All</td>
<td>463</td>
<td>165</td>
<td>35.6%</td>
</tr>
</tbody>
</table>

Interview data were used both for constructing the activity systems of each organisation,
i.e., creating a description of each of the elements of the activity system such as tools used, and
identifying discursive manifestations of contradictions, i.e., discovering tensions in the activity
systems. The data of [redacted], 11 participants from Company B, and 16 participants from
Company C described in Chapters 5 and 6 were therefore also used for the analysis described in
this chapter. Table 27 presents a reminder of the participants by organisation and job type.
Table 27 Interview participants by job role and company

<table>
<thead>
<tr>
<th>Company</th>
<th>Job type</th>
<th>Number of participants</th>
</tr>
</thead>
<tbody>
<tr>
<td>B</td>
<td>Front-line</td>
<td>9</td>
</tr>
<tr>
<td>B</td>
<td>Management</td>
<td>2</td>
</tr>
<tr>
<td>C</td>
<td>Front-line</td>
<td>10</td>
</tr>
<tr>
<td>C</td>
<td>Management</td>
<td>6</td>
</tr>
<tr>
<td>Total</td>
<td>Front-line</td>
<td>27</td>
</tr>
<tr>
<td>Total</td>
<td>Management</td>
<td>18</td>
</tr>
<tr>
<td>Total</td>
<td>All</td>
<td>45</td>
</tr>
</tbody>
</table>

7.2.2 Quantitative Instrument

The research questions addressed in this chapter require a holistic appraisal of how energy organisations are currently enabling learning via the LFI process. Survey instruments incorporating Likert scales, such as the LFIQ, are suitable when aiming to collect the experiences of a large number of participants in an efficient and quantitative manner (Bryman, 2016). The use of the LFIQ in this research allowed the opinions of multiple participants to be numerically consolidated to identify the strengths and weaknesses of each organisations’ LFI process.

The LFIQ consisted of 46 questions, each designed to explore how well a particular step in the LFI process was undertaken with regards to one of the five factors identified by Lukic et al. (2012) as relevant to the LFI process (Margaryan et al., 2018): learning context, type of incidents, participants of learning, learning process and, type of knowledge. Each question asked participants to rate on a scale of one (strongly disagree) to five (strongly agree) how well a specific element of an LFI phase was carried out at their organisation, for example, their organisation listening to ideas and suggestions for improving safety. It was validated through analysis of 781 workers from two energy organisations (Littlejohn et al., 2017). As an instrument developed within the energy sector the LFIQ should be a valid instrument within the context of this thesis. The reliability of the instrument was confirmed through calculation of Cronbach alpha (Field et al., 2013). In terms of the factor structure, the Cronbach alpha of the five scales ranged between 0.87 and 0.94. These values are above the recommended 0.70, indicating that there is internal consistency between the items of each of the survey’s factors (Bland & Altman, 1997). These values are in line with the validation of the LFIQ (Littlejohn et al., 2017).

7.2.3 Qualitative Instrument

As outlined in Section 4.7, the interviews were designed to ensure that enough data was collected to address all of the research questions in this thesis. In relation to the research questions under discussion in Chapter 7, what enables and restrains learning in the context of LFI, the interview questions needed to align with activity theory in order to produce a description of beneficial
practices that enabled learning and to identify contradictions that inhibited learning. The literature on activity theory and methodology offer some general principles for consideration rather than specific instruments (Engeström, 2000; Nardi, 1996). In line with recommendations by Mwanza (2001), the focus of constructing interview questions was on ensuring that sufficient data was collected that would allow a description of the entire activity system to be created. Each question was labelled with the elements of an activity system. The questions related to SNA and learning objectives, those analysed in Chapters 5 and 6, were labelled with their activity system elements, I observed that there would potentially be a lack of data available on the rules and tools of the activity system. To ensure that enough information was collected to allow a description of each element of the activity system, an essential step in ensuring that the system can be considered holistically to identify beneficial practices and contradictions, an additional question was added to the interview protocol. The question asked participants ‘how does [company] share information about incidents?’ Follow-on probes of ‘are there any official activities where the information is used?’ and ‘do you find these activities useful and relevant to your work’ were also prepared to ensure that details on the rules and tools of the LFI system were described in enough detail.

7.2.4 Analysis Approach

LFIQ analysis

Descriptive statistics were calculated based on the responses to the LFIQ for each organisation. For each participant’s answers the mean was calculated for each phase of the LFI process. The overall mean rating of each phase of the LFI process at each organisation was then computed. In addition to calculating the mean of each phase for each respondent, means were calculated for each question in each organisation. The five highest rated items were noted, as were the five lowest items. This allowed specific issues highlighted by the LFIQ to be compared to the tensions arising from the qualitative analysis of the interview data.

Activity theory analysis

In line with other researchers using activity theory, such as Engeström et al. (1996), Montoro (2016), and Scanlon & Issroff (2005), the analysis was conducted in several steps. The initial step in the analysis involved identifying the number of activity systems present, as recommended by Nardi (1996). Then, following the examples of Lukic (2012), Mwanza (2001), and Shih et al. (2013), a description of each activity system was created based on interview data. After the completion of this step beneficial practices that enabled learning at each organisation were identified. Next,
discursive tensions in the interview data were ascertained, based on the approaches of Engeström and Sannino (2011) and Montoro (2016). Finally, the description of the activity systems and tensions were considered together to identify underlying contradictions, in line with Scanlon and Issroff (2005). The identification of contradictions addresses RQ3b, what inhibits learning in the context of LFI. Each of these steps is described in detail below.

**Identification of activity systems**

The basic unit of any analysis utilising activity theory must be the activity system (Engeström, 2000). Activity systems have been differentiated in various ways in the literature. Perhaps the simplest approach is based on job roles (e.g., Larsen et al., 2017). The SNA conducted in Chapter 5 demonstrated that substantial differences existed between the network use of managers and front-line workers, supporting the use of job-role as a dividing factor for distinguishing activity systems. However, Nardi (1996) asserted that the criteria for separation of activity systems should be common objectives. Chapter 6’s thematic analysis provided the opportunity to compare and contrast perceived objectives of the LFI process between management and front-line workers. A statistical comparison between the objectives of the front-line workers and managers did not provide strong enough evidence to support the assumption that there were significant difference in objectives. Correspondingly only a single activity system will be considered in each organisation in this thesis.

**Description of activity system elements**

Mwanza (2001) proposed that a description of an activity system could be constructed by considering the answers to seven questions. Table 28 shows the different aspects of the activity system, and the relevant question to guide construction.
<table>
<thead>
<tr>
<th>Activity System Aspect</th>
<th>Related question</th>
<th>Example from data</th>
</tr>
</thead>
<tbody>
<tr>
<td>Objectives</td>
<td>Why is this activity taking place?</td>
<td>“the safety things are just be aware of this thing as a potential threat” Participant B3</td>
</tr>
<tr>
<td>Subjects</td>
<td>Which individuals are involved in the activity?</td>
<td>n/a</td>
</tr>
<tr>
<td>Tools</td>
<td>What aids are used in order to complete the activity?</td>
<td>“By a multitude of emails, toolbox talks, open discussions, two-way open discussions which is most important, and meetings.” Participant C15</td>
</tr>
<tr>
<td>Rules</td>
<td>What rules and regulations, including cultural norms, affect how the activity is carried out?</td>
<td>“When they are concerned about things they have to come to me and I support them.” Participant A5</td>
</tr>
<tr>
<td>Division of labour</td>
<td>How are responsibilities and tasks distributed and organised among subjects?</td>
<td>“Not always from the refinery manager. It could be on behalf of him, and then sometimes it’ll be from our, our day supervisor, or the field leader.” Participant C6</td>
</tr>
<tr>
<td>Community</td>
<td>Who else is involved in achieving the objectives of the activity?</td>
<td>“When you’re out in the, you walk your round. You always talk to contractors or safety guys who were at the job. And they also have additional information for you” Participant A1</td>
</tr>
<tr>
<td>Outcomes</td>
<td>What is the anticipated end result?</td>
<td>“Well, so you can reduce the accidents in the workplace really” Participant B5</td>
</tr>
</tbody>
</table>

In the case of this project the activity of interest is LFI. There is universal agreement in the literature on the desired outcome of LFI: to minimise the occurrence of incidents in the future (Stemn et al., 2018). Detailed descriptions of the outcomes were therefore not created. Objectives, understood as why LFI is taking place, are described in the literature as learning in order to prevent future incidents (Le Coze, 2013). The thematic analysis conducted in Chapter 6 broke down in detail what participants meant by successful learning in the context of LFI, which
was taken to be the objective of LFI. Similarly, the SNA conducted in Chapter 5 gave insight into who was involved in achieving the objectives of the activity and how labour was divided, i.e., the subject, community, and division of labour elements of the activity system.

Coding of the interview data was therefore used to create a description of the tools and rules elements of the activity system for each organisation, an approach previously used by Lukic (2012) and Shih et al. (2013). Deductive descriptive coding was employed, in other words, any sentences spoken by an interview participant relevant to the questions outlined in Table 28 for either the tools or rules elements of the activity system were coded (Saldaña, 2016). Interview excerpts labelled with the relevant code were used to create a narrative of each element.

**Discursive manifestations of contradictions**

While contradictions are seen as a vital force for activity systems to develop and improve, a fundamental principle of activity theory is that they cannot be directly observed (Engeström, 2000). Engeström and Sannino (2011) proposed that although contradictions could not be observed, they would manifest in the dialogue of subjects. Through the analysis of dialogue it may be possible to deduce underlying contradictions in an activity system, as demonstrated by Montoro (2016). However, it should be stressed that the manifestations themselves are a clue to contradictions, but not contradictions themselves (Sannino, Engeström, & Lahikainen, 2016). Nonetheless, when considered in the wider context of the activity system, contradictions can be identified from dialogue, for example, by tensions indicating that the tool used is not suitable to achieve the activity system objectives (Pea, 1993; Scanlon & Issroff, 2005).

In their methodological article on discursive manifestations of contradictions, Engeström and Sannino (2011) offered one approach for identifying discursive manifestations. The authors suggested that specific linguistic cues be identified, such as the use of rhetoric questions, which they associated with four particular types of manifestations, shown in Table 32, but noted that these are not meant as an exhaustive list of manifestations.
Table 29 Summary of discursive manifestations of contradictions (Engeström & Sannino 2011; Kaatrakoski et al. 2017; Montoro 2016)

<table>
<thead>
<tr>
<th>Discursive manifestation</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dilemma</td>
<td>The existence of multiple evaluations of relative values, decisions, or morals. These differences in perception of value may be inter- or intra-person. It often involves situations where an individual feels the will of others are forced upon them.</td>
</tr>
<tr>
<td>Conflicts</td>
<td>Dispute, resistance, or contention to the ideas or actions of others.</td>
</tr>
<tr>
<td>Critical conflicts</td>
<td>Critical conflicts resemble conflicts, but are within an individual.</td>
</tr>
<tr>
<td>Double binds</td>
<td>Caused by situations in which individuals are presented only with unacceptable options due to the conditions of the activity system.</td>
</tr>
</tbody>
</table>

This approach to identifying discursive manifestations of contradictions was initially applied but failed to capture the complexity of the data. The use of linguistic features and devices are complex and dependent upon context, so it was difficult for simple approaches based on key words or types of phrase to fully capture the tensions hinted at by participants (Carter & McCarthy, 2006). This issue was possibly further compounded by the fact that some participants were non-native English speakers. Instead of using linguistic features to identify tensions, I employed versus coding. In this style of coding labels are described as a set of two opposing categories, such as ‘teachers versus curriculum’ (Saldaña, 2016). While novel in the context of activity theory, this approach is well established in action research and anthropological studies that explore hidden tensions within and between groups (e.g., Altrichter et al., 1993; Wolcott, 2003). The descriptions of different types of discursive manifestations of contradictions in Table 32 all depict a tension between two different forces. For example, a dilemma can be understood as a situation where a subject finds themselves with two or more competing priorities in tension with each other. Versus coding therefore represented an established analysis approach in line with the principles of activity theory.

Initially a deductive coding scheme was created by considering the concepts in tension in the descriptions of manifestations of dilemmas, conflicts, critical conflicts, and double binds. After application to the data and further reflection, in line with recommendations by Saldaña (2011) and Strauss and Corbin (1998), two additional categories were inductively added. The final coding scheme is shown in Table 30.
<table>
<thead>
<tr>
<th>Code</th>
<th>Description</th>
<th>Example from data</th>
</tr>
</thead>
<tbody>
<tr>
<td>Priority VS</td>
<td>Two competing interests are mentioned. These differing interests do not necessarily place the person in a difficult situation, but do require judgements on priorities.</td>
<td>“The old operators knew everything. That’s also a discussion, because now they are following the procedures more.” Participant A16</td>
</tr>
<tr>
<td>Self VS Other</td>
<td>Situations where a person felt like the will of others was imposed upon them.</td>
<td>“So if we’re not making our safety targets then obviously we get financially penalised as a refinery.” Participant C3</td>
</tr>
<tr>
<td>Self VS Self</td>
<td>Expression of an internal struggle, when conflicting values are attempted to be resolved by an individual.</td>
<td>“I only get it done once every 6 months. Or once every 6 months, if he doesn’t pick me up on that I could then be going out to the next job and not do what he’s looking for, and then I wouldn’t be picked up again for another 6 months. So in that case, it’s probably best, but obviously you can’t be checked on all the time. It wouldn’t work.” Participant B1</td>
</tr>
<tr>
<td>Self VS Situation</td>
<td>Description of times when a person finds themselves in a situation that is impossible to resolve.</td>
<td>“We defensively have to block outages, and basically if we are unaware of that how can we actually override other people getting killed there” Participant A8</td>
</tr>
<tr>
<td>Self VS Human nature</td>
<td>Unavoidable difficulties arising from how humans process information and perceive risk.</td>
<td>“He said himself in the video, he said ah I’ve been doing this for years and years and years, I just didn’t think” Participant B2</td>
</tr>
<tr>
<td>Self VS System</td>
<td>Examples of times when the LFI process was insufficient for a person’s needs.</td>
<td>“I mean some of the procedures are pages and pages long so you would never ever remember every single step” Participant C11</td>
</tr>
</tbody>
</table>
Identification of contradictions

The final step of analysis drew on all the findings within this thesis. This began by considering the discursive manifestations of contradictions identified in each organisation and recognising which issues seemed similar across organisations. Finally, following the example of Scanlon and Issroff (2005), conclusions were drawn regarding which elements of the activity systems were in tension leading to a contradiction.

7.3 Results

7.3.1 LFIQ

*Company A*

[redacted]

*Company B*

The results of Company B’s LFIQ responses are shown in Table 31, Table 32, and Table 33.

Reporting appeared to be the strongest phase of Company B’s LFI process, as it had the highest overall mean and four of the five highest rated items related to this phase. Over 75% of participant agreed or strongly agreed with each of these four items relating to reporting.

According to the mean of the phases displayed in Table 31, developing incident alerts was also a strength of Company B. Nonetheless, the lowest rated item of the questionnaire also related to reporting: ‘We can report incidents without fear of repercussions.’

<table>
<thead>
<tr>
<th>LFI process phase</th>
<th>Mean (n=47)</th>
<th>Standard Deviation</th>
<th>Minimum</th>
<th>Maximum</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reporting</td>
<td>4.03</td>
<td>1.26</td>
<td>1.00</td>
<td>5.00</td>
</tr>
<tr>
<td>Investigating</td>
<td>3.53</td>
<td>1.25</td>
<td>1.00</td>
<td>5.00</td>
</tr>
<tr>
<td>Developing Incident Alerts</td>
<td>3.71</td>
<td>1.01</td>
<td>1.00</td>
<td>5.00</td>
</tr>
<tr>
<td>Disseminating</td>
<td>3.47</td>
<td>1.14</td>
<td>1.00</td>
<td>5.00</td>
</tr>
<tr>
<td>Contextualising</td>
<td>3.54</td>
<td>1.07</td>
<td>1.00</td>
<td>5.00</td>
</tr>
<tr>
<td>Implementing Actions</td>
<td>3.54</td>
<td>1.11</td>
<td>1.00</td>
<td>5.00</td>
</tr>
</tbody>
</table>
In terms of the weakest areas for Company B, the disseminating phase was rated the lowest on average, and two of the lowest rated items were connected to the distribution of incident-information. In particular, over a third of participants disagreed or strongly disagreed with ‘we are routinely informed about the progress and outcomes of incident investigations’. [redacted].

<table>
<thead>
<tr>
<th>Question</th>
<th>LFI process phase</th>
<th>Mean (n=47)</th>
<th>Standard Deviation</th>
<th>Minimum</th>
<th>Maximum</th>
</tr>
</thead>
<tbody>
<tr>
<td>Managers consistently encourage reporting of incidents.</td>
<td>Reporting</td>
<td>4.45</td>
<td>1.01</td>
<td>1.00</td>
<td>5.00</td>
</tr>
<tr>
<td>We can report both incidents and near misses.</td>
<td>Reporting</td>
<td>4.43</td>
<td>1.05</td>
<td>1.00</td>
<td>5.00</td>
</tr>
<tr>
<td>Our organisation has a system in place that allows us to easily report incidents.</td>
<td>Reporting</td>
<td>4.30</td>
<td>1.07</td>
<td>1.00</td>
<td>5.00</td>
</tr>
<tr>
<td>Incidents get reported using formal systems rather than informally to colleagues.</td>
<td>Reporting</td>
<td>4.13</td>
<td>1.20</td>
<td>1.00</td>
<td>5.00</td>
</tr>
<tr>
<td>We receive incident-information relevant to our work.</td>
<td>Disseminating</td>
<td>3.96</td>
<td>0.97</td>
<td>1.00</td>
<td>5.00</td>
</tr>
</tbody>
</table>

[redacted]. In Company B two of the five lowest rated items inquired about the contextualising process, specifically referring to giving and receiving feedback on incident alerts. Over a quarter of participants from Company B disagreed or strongly disagreed with these items. This aligns with the SNA of Chapter 5, which noted that the engineers in Company B were relatively isolated from others and few opportunities for contextualising incident-information outside their team meetings.
Table 33 Company B’s 5 lowest rated LFIQ items

<table>
<thead>
<tr>
<th>Question</th>
<th>LFI process phase</th>
<th>Mean (n=47)</th>
<th>Standard Deviation</th>
<th>Minimum</th>
<th>Maximum</th>
</tr>
</thead>
<tbody>
<tr>
<td>We can report incidents without fear of repercussions.</td>
<td>Reporting</td>
<td>2.87</td>
<td>1.20</td>
<td>1.00</td>
<td>5.00</td>
</tr>
<tr>
<td>We are routinely informed about the progress and outcomes of incident investigations.</td>
<td>Disseminating</td>
<td>2.94</td>
<td>1.24</td>
<td>1.00</td>
<td>5.00</td>
</tr>
<tr>
<td>At our worksite, we often give feedback to the authors of incident alerts.</td>
<td>Contextualising</td>
<td>3.04</td>
<td>1.08</td>
<td>1.00</td>
<td>5.00</td>
</tr>
<tr>
<td>We always receive responses to any feedback we give on incident alerts.</td>
<td>Contextualising</td>
<td>3.15</td>
<td>1.06</td>
<td>1.00</td>
<td>5.00</td>
</tr>
<tr>
<td>People who do not regularly use computers receive the same information about incidents as those who do.</td>
<td>Disseminating</td>
<td>3.19</td>
<td>1.02</td>
<td>1.00</td>
<td>5.00</td>
</tr>
</tbody>
</table>

**Company C**

As can be seen from Table 34, like in Company A and B, reporting was the LFI process phase with the highest mean rating in Company C. All phases in the LFI process appeared to be scored relatively well, with mean ratings of at least 3.77 out of 5.00.
As with Company B, Company C’s highest rated items on the LFIQ predominantly related to reporting, with over 90% of participants agreeing or strongly agreeing with the four items on reporting in Table 41. Table 41 also shows that one item related to dissemination was highly regarded by the Company C workers: ‘we discuss incidents, and what to do to prevent them, with our colleagues outside of safety meetings and safety specific communications’, with 93% of participants agreeing or strongly agreeing with the item. In Chapter 5’s SNA Company C appeared to invest resources into ensuring that front-line workers had the opportunities to attend a variety of meetings, where incidents could be discussed outside of safety specific communications. These meetings would also involve managerial level workers. The opportunities created by these meetings could explain why this item was so highly rated.

### Table 34 Results of Company C’s LFIQ by LFI process phase

<table>
<thead>
<tr>
<th>LFI process phase</th>
<th>Mean (n=86)</th>
<th>Standard Deviation</th>
<th>Minimum</th>
<th>Maximum</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reporting</td>
<td>4.27</td>
<td>0.89</td>
<td>1.80</td>
<td>5.00</td>
</tr>
<tr>
<td>Investigating</td>
<td>3.86</td>
<td>0.91</td>
<td>1.00</td>
<td>5.00</td>
</tr>
<tr>
<td>Developing Incident Alerts</td>
<td>3.81</td>
<td>0.78</td>
<td>2.43</td>
<td>5.00</td>
</tr>
<tr>
<td>Disseminating</td>
<td>3.77</td>
<td>0.87</td>
<td>1.78</td>
<td>5.00</td>
</tr>
<tr>
<td>Contextualising</td>
<td>3.83</td>
<td>0.84</td>
<td>2.46</td>
<td>5.00</td>
</tr>
<tr>
<td>Implementing Actions</td>
<td>3.87</td>
<td>0.77</td>
<td>2.17</td>
<td>5.00</td>
</tr>
</tbody>
</table>
Table 35 Company C’s 5 highest rated LFIQ items

<table>
<thead>
<tr>
<th>Question</th>
<th>LFI process phase</th>
<th>Mean (n=86)</th>
<th>Standard Deviation</th>
<th>Minimum</th>
<th>Maximum</th>
</tr>
</thead>
<tbody>
<tr>
<td>Our organisation has a system in place that allows us to easily report incidents.</td>
<td>Reporting</td>
<td>4.51</td>
<td>0.69</td>
<td>1.00</td>
<td>5.00</td>
</tr>
<tr>
<td>We can report both incidents and near misses.</td>
<td>Reporting</td>
<td>4.51</td>
<td>0.68</td>
<td>2.00</td>
<td>5.00</td>
</tr>
<tr>
<td>Incidents get reported using formal systems rather than informally to colleagues.</td>
<td>Reporting</td>
<td>4.41</td>
<td>0.67</td>
<td>2.00</td>
<td>5.00</td>
</tr>
<tr>
<td>Managers consistently encourage reporting of incidents.</td>
<td>Reporting</td>
<td>4.33</td>
<td>0.80</td>
<td>1.00</td>
<td>5.00</td>
</tr>
<tr>
<td>We discuss incidents, and what to do to prevent them, with our colleagues outside of safety meetings and safety specific communications.</td>
<td>Dissemination</td>
<td>4.30</td>
<td>0.63</td>
<td>2.00</td>
<td>5.00</td>
</tr>
</tbody>
</table>
Table 36 shows the five lowest rated items from Company C’s LFIQ results. Two of the questions related to dissemination were common to all three organisations as being among the lowest rated items: ‘people who do not regularly use computers receive the same information about incidents as those who do’ and ‘we are routinely informed about the progress and outcomes of incident investigations’. In Company C 17% and 22% of participants respectively rated these items as either a one or a two. In addition, two other items from Company C’s five lowest rated were common with Company B, with around 25% of the respondents in Company C rating the items as a one or a two: ‘we always receive responses to any feedback we give on incident alerts’ and ‘at our worksite, we often give feedback to the authors of incident alerts’.
Table 36 Company C’s 5 lowest rated LFIQ items

<table>
<thead>
<tr>
<th>Question</th>
<th>LFI process phase</th>
<th>Mean (n=86)</th>
<th>Standard Deviation</th>
<th>Minimum</th>
<th>Maximum</th>
</tr>
</thead>
<tbody>
<tr>
<td>We always receive responses to any feedback we give on incident alerts.</td>
<td>Contextualising</td>
<td>3.00</td>
<td>0.96</td>
<td>1.00</td>
<td>5.00</td>
</tr>
<tr>
<td>People who do not regularly use computers receive the same information</td>
<td>Dissemination</td>
<td>3.16</td>
<td>0.85</td>
<td>1.00</td>
<td>5.00</td>
</tr>
<tr>
<td>about incidents as those who do.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>At our worksite, we often give feedback to the authors of incident</td>
<td>Contextualising</td>
<td>3.17</td>
<td>1.00</td>
<td>1.00</td>
<td>5.00</td>
</tr>
<tr>
<td>alerts.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>When preparing incident alerts, we adapt the content to suit the different</td>
<td>Developing an</td>
<td>3.29</td>
<td>0.91</td>
<td>1.00</td>
<td>5.00</td>
</tr>
<tr>
<td>people receiving them.</td>
<td>incident alert</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>We are routinely informed about the progress and outcomes of incident</td>
<td>Disseminating</td>
<td>3.33</td>
<td>1.07</td>
<td>1.00</td>
<td>5.00</td>
</tr>
<tr>
<td>investigations.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Summary of LFIQ results

In terms of the beneficial practices within the LFI process all three organisations appeared to excel at providing an infrastructure to ensure that incidents could be reported easily. [redacted].

On the other hand, some parts of contextualisation appeared to be difficult for all three organisations. Items with low ratings from the LFIQ usually related to what the SNA conducted in
Chapter 5 would term information gathering: purposeful exchange of incident-information outside the structured dissemination process, such as providing feedback on incident alerts. Aspects of the dissemination process were also rated relatively low in all organisations, such as ensuring people who did not have access to computers received alerts or receiving responses when feedback on an incident was provided.

7.3.2 Description of Activity Systems

Creating descriptions of the activity systems drew upon the analysis conducted in Chapters 5 and 6 and focused on highlighting beneficial practices across the three organisations. The following section will present the description of each organisation’s LFI system, organised by the six elements of an activity system: objectives, subjects, tools, community, division of labour, and rules (Engeström, 2001).

**Company A**

[redacted]

**Company B**

**Objectives**

The thematic analysis conducted in Chapter 6 showed that the following were viewed as desirable learning products by most participants:

- Updated best practice
- Improved knowledge of risks
- Updated procedures
- Improved procedural knowledge and skills
- Additional layers of safety protection

In terms of objectives for ensuring an effective learning, the following were mentioned by most participants:

- Monitoring, i.e., collecting data on how work is carried out and what incidents occur
- Incident-information is delivered to workers in an impactful manner
- Open communication
- Workers possess a safety-oriented mindset
- Workers have an accurate perception of the danger associated with hazards
Workers know where to find relevant incident-information
Incident-information is embedded into organisational memory
There are formal pathways to allow exchange of incident-information
Impromptu communication about incidents supplements the structured exchanges of information
Safety is an organisational value
The organisation’s strategy reacts to incidents
The organisation is transparent in its communication and decisions related to incidents

Subjects
The subjects of the activity system were engineers in Company B from departments dedicated to installing equipment and repairing it.

Tools
Company B had a dedicated incident reporting system to facilitate reporting and investigations. The system was not just an electronic database, but also included a hotline that engineers could call to register an incident. Reporting via a hotline meant that reports could be recorded in a consistent format, and that relevant people, such as the worker’s manager, the district manager, and the union representative, were immediately notified with the details of an incident. The report could be checked at any time for an update on the investigation progress.

All participants from Company B mentioned that they regularly received emails with details of incidents. The incident alerts were not just distributed by email. In addition, an official organisational social media platform, Yammer, was used to provide details of incidents. However, Yammer was mentioned by only two participants, who both commented that they rarely opened the application. WhatsApp was an additional tool used to communicate in general, including about incident alerts. In contrast to Yammer, WhatsApp was used frequently by workers. Two types of meetings for front-line engineers supported the distribution of written incident alerts. Team meetings were held on a regular basis, approximately every month, and meetings with a safety representative were held every three months. In these meetings the team supervisor or safety representative presented information on an incident, detailed what had happened, and how a similar incident could be avoided. Two participants noted that the human resources system was used to keep track of who had received what incident-information, as they were required to mark presentations and videos that they had seen in the training section. If a large incident occurred impromptu online meetings were also held to update the whole organisation instantly about the event and answer questions.
Besides the incident reporting system, emails, and meetings, a digital platform was used to support engineers in completing their work. Several participants noted that procedures and best practice were often updated or varied depending on the hardware installed in a customer’s home. Before each job the engineers would be presented by the computer system with relevant equipment faults and the history of the job location. This was further supplemented by designated coaches and safety assurance engineers, who could be contacted if an engineer was unsure about any aspect of a task.

The coaches, managers, and safety assurance engineers also formed part of the mechanism for continued monitoring of potential issues, as they all conducted regular audits of the work carried out by engineers. Monitoring of potential incidents was also carried out by examining incident trends. While it was only described by Participant B7, a manager, another monitoring device that had been used by Company B once was a questionnaire designed to highlight gaps in an engineer’s knowledge.

**Community**
The front-line engineers, their immediate management, the HSE department, safety assurance engineers, and the district management were mentioned by participants as having roles in the LFI process.

**Division of labour**
The division of labour in Company B was described through the SNA conducted in Chapter 5. There was no specific team dedicated to LFI in addition to the HSE department. All decisions on which information was relevant to which groups was made by the HSE department, who were also responsible for distributing all incident alerts.

The management in Company B participated in district level meetings where incident alerts were discussed, and the relevance of incidents distributed by the HSE department was evaluated. These meetings were also attended by the district manager. The management of Company B included team supervisors, who were not actively involved in carrying out technical tasks. As in the other organisations, team supervisors were a bridge to the wider discussions as the facilitator of the monthly team meetings.

While there was no specific LFI team in Company B, the safety assurance engineers were vital partners to the engineers in preventing incidents. Safety assurance engineers were involved in the distribution of incident-information at regular meetings, but additionally carried out audits to actively monitor risks in work practice. Safety assurance engineers were also designated
experts in safety, and were the first person that most engineers would contact with safety concerns.

Within teams designated coaches played a similar role to safety assurance engineers. As technical experts, coaches were aware of different risks and best practices derived from incidents and would be contacted for advice on safety issues due to this. Coaches also played an active role in conducting audits and monitoring risks. However, they were not responsible for distributing incident-information.

Front-line engineers were primarily recipients of incident-information. While feedback on equipment could be provided on their digital platform, they were rarely asked to provide feedback on incidents.

Rules
Procedures were official guidelines that embedded lessons learnt from incidents in work practice. As rules often varied depending upon the situation at a customer’s house, Company B had rules designed to ensure data quality, such as requiring engineers to submit notes on each location or confirm that they had read relevant safety notices before conducting a job. This was also seen to protect engineers against legal action by customers if an incident occurred. Company B’s activity in LFI was influenced by the wider laws and expectations of society.

The influence of incidents could also be seen on the organisation’s rules, as two participants spoke about the dissolution of a productivity bonus. The bonus had been putting pressure on engineers, which in turn had compromised safety. However, three participants did mention that they felt that teams were still judged based on the number of incidents that an organisation had experienced.

Company C
Objectives
As with Company B, the objectives of the activity system in Company C were taken from the thematic analysis I conducted in Chapter 6. The following were considered desirable products of learning by most participants:

- Updated best practice
- Improved knowledge of risks
- Updated procedures
- Additional layers of safety protection
• Improved procedural knowledge and skills

The objectives mentioned by most participants relating to facilitating an effective learning process were:

• Monitoring, i.e., collecting data on how work is carried out and what incidents occur
• Incident-information is delivered to workers in an impactful manner
• Open communication
• Workers possess a safety-oriented mindset
• Workers have an accurate perception of the danger associated with risks
• Incident-information is embedded into organisational memory
• There are formal pathways to allow exchange of incident-information
• Impromptu communication about incidents supplements the structured exchanges of information
• Safety is an organisational value

Subjects
The subjects of the activity system of Company C were those involved with production. This included both front-line workers and the managers of the production process.

Tools
There were a variety of tools used to mediate LFI at various stages to achieve the objectives outlined above. In a similar manner to Company B, meetings and discussions were one tool that enabled incident-information to be delivered to workers.

Email was also mentioned by all participants as a formal pathway for communicating incident-information; emails summarising incidents were regularly sent. Emails and team meetings were supplemented by presentations from either the HSE department, or those involved in incidents at other organisations. These presentations focused on improving the knowledge of workers on both risks and procedures. If necessary, training was conducted to enhance skills related to procedures.

Like Company B, Company C had an incident reporting system, which consisted of a computer programme that could be accessed by anyone. This was used to report incidents, but also follow their progress. Participants in Company C identified two types of incident investigation techniques depending on the severity of the incident: after action reviews and root cause analysis. After action reviews were used as a small-scale opportunity to assess if changes were
necessary after an incident and were undertaken by a variety of employees. Root cause analyses represented an in-depth analysis of incident causes and were undertaken by specialists.

Several tools were described by participants that allowed Company C to monitor and evaluate risks. As in Company B, audits were mentioned by almost all participants as a tool that constantly allowed assessment of risks involved in work that could lead to incidents. The results of audits, combined with incident statistics and trends, were used to decide priorities for the kinds of incident-information distributed. As modification of procedures was a common response following an incident, audits provided opportunities to observe whether recommendations were implemented. Handover sheets additionally were used as a way for shifts to keep updated on what had happened while they had been off-duty. Another tool used by workers was a database of information related to procedures. It contained, for example, information on chemicals or protective equipment. Other tools, such as procedures, permits, training, and checklists, had incorporated information from incidents into them which then influenced the way that daily tasks were carried out.

Community

As discussed in chapter 5, the production department’s community extended beyond their immediate colleagues. The refinery leadership team, the HSE department, and the maintenance department all played a role in the LFI system.

Division of labour

As in Company B, the HSE department were responsible for finding out incident-information and distributing incident alerts. However, when a more in-depth discussion on an incident was deemed necessary, the incident-information was sent to the training department who created and distributed presentations.

[redacted]. The management would meet with their colleagues to decide which incidents were relevant to their teams. These meeting would inform production priorities and would be followed by incident-information being cascaded to front-line teams. Participation in professional networks and conferences also provided management with opportunities to collect information on incidents besides those distributed by the HSE department.

The front-line of Company C, however, differed from Company B. As shown by the SNA in Chapter 5, the front-line workers participated in a variety of cross-organisational meetings where incidents might be discussed. While the team supervisor was responsible for communicating cascaded incident-alerts to his team, the supervisor was not the only bridge between front-line workers and the wider organisation.
Rules
Formal rules outlined clearly the expectations of reporting and incident investigations. In addition, the rules were often used to signal importance of specific presentations or discussions, as workers were required to sign that they had received the most important incident alerts. The notion of importance of information was also observed in a cultural acceptance that emails on incidents should be read where possible, but there was no check so could in theory be deleted if deemed irrelevant. Rules were also used to enforce changes that arose following an accident investigation, such as mandatory attendance of training related to the cause of an incident.

Many participants mentioned cultural norms that were associated with reporting incidents. Officially any worker could stop production and raise concerns about potential incidents, and several participants mentioned that they had never received a negative reaction when raising a safety concern. In practice, it was accepted that a front-line worker would discuss issues with their immediate colleagues or the team supervisor to get a second opinion, unless faced with an imminent hazard.

As in Company B procedures were official instructions on how to carry out tasks. Some participants discussed how they more closely followed procedures after incidents had highlighted the reason for certain steps. Moreover, two participants mentioned that they felt the production team had a responsibility to ensure that other workers followed procedures correctly.

Summary of descriptions of the activity systems
The description of the activity systems presented above can be used to further extend the narrative of the results LFIQ in terms of what the three organisations in this thesis do to enable LFI, thus addressing the first part of this chapter’s research question. While there were many similarities between the different organisations’ LFI systems, each organisation appeared to have a unique practice that others could benefit from.

[redacted].

Tools supporting communication and information flow in Company B
The technology used in Company B was unique due to the different nature of their work: rather than working on the same site everyday with the same equipment, the engineers in Company B visited different houses with different equipment. In order to cope with the variety in environment, the digital platform in Company B provided workers with relevant technical information and an overview of the site history, including hazards such as dogs. While not information on specific incidents, the information provided detailed risks that were relevant to
the work about to be undertaken by engineers. [redacted], this allowed workers to connect information directly to a process rather than in reaction to an out of context incident. The digital platform could easily be expanded to provide incident alerts on relevant topics just before workers undertook related work.

Workers in Company B were also the only participants to mention the use of social media platforms. While Yammer was rarely used, WhatsApp appeared to be a useful tool for communication. Participants mentioned that it allowed the exchange of pictures, aiding coaches and safety assurance engineers in their assessment of situations without physically being in the same location as the engineer. WhatsApp also allowed discussions to occur asynchronously. As the use of phones was not allowed when driving or in a customer’s house, this allowed managers, coaches, and safety assurance engineers to respond when they had the opportunity to check their phones.

The use of technology to provide risk related information relevant to the day’s tasks and aid communication would support Company B in achieving their learning objectives in several ways. Firstly, it would remind workers of procedures and best practice. Secondly, it could improve the knowledge of the worker on risks. The use of social media provided a platform to enable impromptu discussions despite workers’ separation.

Division of labour in Company C
As already noted, the LFIQ results appeared to corroborate the findings of Chapter 5’s SNA. Front-line workers were responsible for representing their teams at inter-departmental meetings. This provided opportunities to communicate with colleagues from different teams on incidents. One of Company C’s highest rated items on the LFIQ was ‘we discuss incidents, and what to do to prevent them, with our colleagues outside of safety meetings and safety specific communications’. The more diverse networks that resulted from the participation of workers in Company C in meetings external to their department were likely to have contributed to the positive reaction of workers to this questionnaire item. From the viewpoint of learning objectives, this is likely to improve how impactful the delivery of the incident-information is, as incidents are discussed by fewer people with similar backgrounds, requiring more explicit verbalisation of assumptions (Mercer, 2013; Nonaka & Takeuchi, 1995). The meetings also expanded the networks of front-line workers, creating more formal pathways for communication, and more opportunities for impromptu interactions.
7.3.3 Contradictions in LFI

While each organisation faced their own difficulties, the purpose of this analysis was to understand what barriers were faced across the three organisations, representing industry-wide issues. Overcoming internal contradictions is how systems make transformational changes (Engeström & Sannino, 2010), however until they are overcome, contradictions represent barriers than can impair an activity system from achieving its objectives. Focusing on each organisation individually might highlight some tensions that could be addressed to incrementally improve the LFI processes. However, this thesis has the goal of identifying contradictions that if addressed could be considered as transformational learning for the whole sector. Correspondingly four contradictions were identified that were appeared to be present at all three organisations. The four contradictions were:

- Membership of multiple activity systems, where tools were not only influenced by external bodies, such as the legal team, but designed to try and simultaneously achieve the objectives of both safety and learning. While safety and learning are often compatible prior research has found significant differences that can lead to issues if a distinction between these two different activities is not made (Littlejohn et al., 2014).

- Perceived irrelevance of incident alerts. This was partly due to insufficient tools for those sending the alerts to assess which parts of an organisation would find an incident to be relevant. However, an additional reason for this contradiction appeared to be that participants often considered the incidents of strangers to be due to incompetence (Tetlock, 1985). Incidents were hence dismissed as irrelevant as workers did not actively consider the situational aspects of an incident.

- Inconsistent underpinning pedagogy, where the LFI process was executed differently depending on the team or incident. This contradiction was found at the organisational level, where steps such as evaluating the effectiveness of implemented changes were not always carried out. It was also described at the individual level, where how team supervisors presented information varied.

- Causality of incidents, where the inherent probabilistic nature of incidents meant that workers did not know if incidents occurred due to a lack of learning and safety, or if they were just unlucky.

The different coding of discursive manifestations of these contradictions are presented below as evidence to support the deduction of the contradictions. The identification of the contradictions was approached in a similar manner to thematic analysis where individual codes were identified and then grouped into themes. In other words, the coding categories were
systematically applied to data, and then considered holistically to understand what contradictions would result in these kinds of tensions.

**Contradiction 1: Membership of multiple activity systems**

**Description of the contradiction**

In their comparison of safety culture and learning culture Littlejohn et al. (2014) noted that while there were several aspects of the two that aligned, such as the need to be able to communicate openly, safety and learning culture differed in several important ways. For example, a culture that facilitates learning would allow individuals to make mistakes, while avoiding mistakes is one of the goals of safety (Hollnagel, 2014). LFI is a process that should enable learning but, as was the case with all three organisations in this thesis, is usually under the remit of the HSE world, as the desired outcome is to reduce incidents. Furthermore, as outlined by Rasmussen (1997) and Lundberg et al. (2010), all safety tools and approaches are themselves situated within a complex social landscape, influenced by economic, legal, and political agendas. When considering this from the perspective of activity theory, each of these agendas are accompanied by their own objectives, and the actions of individuals (i.e., subjects) and their colleagues (i.e., the community) must try to balance competing objectives, which have potentially contradictory goals.

Primarily the first contradiction discovered in the analysis was concerned with a lack of acknowledgement that safety and learning were not necessarily always compatible. Learning was perceived as a method by which to reduce incidents, in other words, a way to create a safe environment. However, this view led to the creation of tools that were used in ways that furthered organisational safety, but may have inhibited learning as tasks required less active thought. For example, protection provided by improved equipment reduced the need for workers to understand the theory behind their practice. A further layer to this contradiction was pressures from other activities undertaken by the workforce, such as production, and other activity systems, such as the legal department, that were incompatible with the objectives of either safety or learning. Figure 31 shows a diagram of this contradiction between the objectives of multiple activity systems and the tools of the LFI activity system.
Discursive manifestations of contradiction 1

As can be seen from Table 37, the versus coding, designed to find manifestations of contradictions in dialogue, found various types of tensions that were evidence of pressures of the competing objectives of different activity systems.

Table 37 Discursive manifestations of contradiction 1

<table>
<thead>
<tr>
<th>Versus code</th>
<th>Reference count</th>
</tr>
</thead>
<tbody>
<tr>
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<td>11</td>
</tr>
<tr>
<td>Self vs others</td>
<td>38</td>
</tr>
<tr>
<td>Self vs self</td>
<td>23</td>
</tr>
<tr>
<td>Self vs situation</td>
<td>44</td>
</tr>
<tr>
<td>Self vs system</td>
<td>17</td>
</tr>
</tbody>
</table>

The ‘priority versus priority’, ‘self versus others’, and ‘self versus situation’ codes were all used relatively frequently with relation to the first contradiction. As would be expected from the nature of the contradiction, the ‘priority versus priority’ codes were usually used by participants to describe situations where they had to balance different goals. For example, one participant in Company B observed that the balance had altered in favour of safety recently with a change in
management. Participant B5 describes a recent experience where he had reached out to a new senior manager with a safety concern. In the past he never would have undertaken such an action, as production was the primary focus. Participant C5 also described the need to balance time spent reading incident alerts and time spent on core tasks:

‘So although we get them sent through to us, we very rarely read them. There’s only so many hours in the day’

Participant C5, Front-line

Nevertheless, as shown by the codes in the ‘self versus others’ category, competing priorities were not just acknowledged by workers but described as others imposing their will on workers. The ‘self versus situation’ codes also manifested in similar ways, although with an understanding that the situation was unavoidable. [redacted]

In this case, the incident alert which was intended as a tool to spread information on risks had become no longer fit to serve its purpose. An interesting conflict that emerged in multiple categories across the coding scheme related to procedures. Procedures are tools designed to act as a guide for workers on how to carry out their work (Lundberg et al., 2009). However, the written word is open to interpretation and there can be a gap between what the writer of the procedure intended and how the procedure is understood (Pea, 1993). As discussed in Chapter 6, updating procedures and either making them more explicit or expanding the range of situations that they cover is an objective of LFI, as it represents a form of embedding knowledge into daily tasks.

From the perspective of safety, the less open to interpretation that a procedure is the better, as that should help workers to perform tasks consistently in a safe manner. However, in the interviews it emerged that there was at least a balance between operators possessing the skills to complete their tasks successfully and over detailed procedures that contained too much information:

[redacted]
‘I’m not an expert on excavations. I issue permits for them but that’s not my area of expertise. I just know at 1.2 m we need to do a gas test, it’s classed as a confined space and all the bits in my permit system’

Participant C5, Front-line

In more extreme manifestations, however, procedural changes were seen as either evidence of a lack of trust by the organisation in its workers, or as actually detrimental to the successful completion of work:

[redacted]

‘We’ve adopted it in this country on the strength of America. And... at times it’s held us up because we’ve not been able to get to the figure that they wanted... so from that point of view I think that was a backward step. But I can see why they did it.’

Participant C6, Front-line

Chapter 6 discussed that procedures should in theory be a form of organisational learning; when workers are unsure of what to do procedures can be reference points of embedded knowledge that has been garnered from incidents. However, from the perspective of safety, procedures are in place to standardise work. This can cause them to become unsuitable tools for learning as they impact the motivation of workers to learn and decrease the need for background knowledge of risks.

Another example of a tool whose effectiveness for learning was reduced in order to support safety was email. As shall be discussed below, participants at all three organisations felt that they received a lot of emails regarding incidents. On the one hand participants felt that this showed the importance of safety, but, conversely, some also commented that it could feel like the organisation was underestimating workers:
‘They don’t think you’ve got any common sense sometimes. They just keep firing things at you to read, but it’s something that you’ve read the previous month or the month before that.’

Participant C14, Front-line

Another participant noted that the constant reminders of similar subjects seemed redundant:

‘We’re told to risk assess and everything before, so being briefed on it at a [team meeting] to do it again, I don’t know how that’s going to change anything.’

Participant B2, Front-line

Part of the issue appeared to be a difference in the purpose of sending around incident-information from a safety perspective versus a learning one. Safety was associated with a general mindset. [redacted]

Safety was described as an outlook on work that was not always conscious. 12 participants said that they did not think that anything needed to change after receiving an incident alert, rather that the alerts were designed to remind workers of hazards and to work slowly:

‘They would take a bit more time and what they are actually doing. So be a bit more cautious.’

Participant B1, Management

In contrast, the learning that incident alerts try to prompt in individuals requires active reflection on information (Margaryan et al., 2018). As with procedures, emailing incident alerts could become a tool that does not facilitate learning, as workers interpret its purpose through the lens of safety objectives.

Both the examples of procedures and emails reflect another difference that can cause tools used for safety to be unsuitable for achieving learning objectives: the frequent need for change. In all organisations it was observed that changes were constantly happening; as there
were always incidents to learn from there was always something to change in either procedures, best practice or the equipment used. However, while participants understood that constant change was necessary, they found it difficult to keep up to date with current practice:

‘But there’s so much that they have to keep on top of, because the rate of change is just incredibly fast over here.’

Participant B7, Management

‘It just feels sometimes people just get a bit punch drunk with all the changes. You’re always changing, you’re always trying to ram something else down the throats. And I think they probably get a bit fed up with at times.’

Participant C16, Management

As updates occurred frequently, organisations had limited time to engage deeply with any incident or the changes following an incident. As learning is an active process that requires time, and there is a limit to the amount of information that a person can engage with (Paas, Renkl, & Sweller, 2010), this constant change would reduce the ability of individuals to develop knowledge of risks or procedures. It would additionally hinder the motivation of workers to learn, and the high frequency of alerts would reduce their impact. All of these are objectives of learning that emerged from the thematic analysis conducted in Chapter 6.

Contradiction 2: Perceived irrelevance of incident alerts

Description of the contradiction
One of the most obvious issues that 31 participants mentioned was a perceived irrelevance of the incident-information that they received. Examination of the discursive manifestations of this contradiction showed two issues in the activity system that caused this outlook. The first tension in the activity system was the disconnect between those subjectively selecting targets to receive information and those receiving it. The other cause of this contradiction, however, related to how workers thought about incidents that occurred in other locations.

The first part of this contradiction was previewed in the discussion of Chapter 5: primarily the LFI process views incident-information as something that is disseminated from the HSE
department to others. This formal information flow was supplemented by other uses of networks, but tools were not in place to send information on a regular basis back to the HSE department. This gap in turn led to the HSE department receiving no feedback on how accurately they chose teams to recent relevant incident alert. As the daily work of the HSE department is relatively removed from the day to day tasks of front-line workers, in-depth knowledge of every process would be required to successfully subjectively choose which groups an incident would be relevant to. Tools that provide feedback on how relevant different groups found an incident would reduce the need for intimate knowledge of all procedures, but the current iterations of dissemination tools lacked the ability to collect such information.

The second part of the contradiction was more subtle. Humans automatically consider the events of others in a different way to the events that they were subjected to (Jones & Nisbett, 1987). A worker will understand the reasons behind the events that they were a part of, and attribute any undesirable events to circumstances. Alternatively, the events of others will be viewed as a result of the incompetency of an individual (Tetlock, 1985). This difference in the way the causes of events were understood was apparent in the data.

While there are two distinct causes for the second contradiction, the result was that many workers chose not to engage with incident-information due to it being perceived as irrelevant. The activity system lacked the tools necessary to enable those distributing information to know which incidents were relevant to which groups, or to enable workers to move past subconscious judgements. Figure 32 shows the insufficient tools of both the HSE department in distribution of incident alerts and the front-line workers who did not actively engage with the incident alert.

**Figure 32** Insufficient tools to provide subjects with information they perceive as relevant
Discursive manifestations of contradiction 2

The distribution of codes relating to the second contradiction, that the activity systems involved in LFI lacked the tools necessary to provide incident-information that seemed relevant, is shown in Table 38.

<table>
<thead>
<tr>
<th>Versus code</th>
<th>Reference count</th>
</tr>
</thead>
<tbody>
<tr>
<td>Priority vs priority</td>
<td>82</td>
</tr>
<tr>
<td>Self vs human nature</td>
<td>45</td>
</tr>
<tr>
<td>Self vs others</td>
<td>21</td>
</tr>
<tr>
<td>Self vs self</td>
<td>13</td>
</tr>
<tr>
<td>Self vs situation</td>
<td>24</td>
</tr>
<tr>
<td>Self vs system</td>
<td>15</td>
</tr>
</tbody>
</table>

As with the first contradiction, there were many acknowledgements of different priorities by participants. In the case of the second contradiction this usually related to a balance between the time invested in making sure that everyone had seen some information and time spent doing core tasks.

‘With the emails I’d say that’s, it’s just naturally you have a little less focus on what the email is about. Especially if you are sort of working at the time you get the email. You might have a look at it, skim it roughly to get the idea.’

Participant B3, Front-line

However, across the coding categories of manifestations it became apparent that workers viewed many incident alerts that they received as irrelevant. This was often due to the incident being seen as too small to be worth investigating time into considering, or that it was not relevant to their particular circumstances:
‘There’s some really irrelevant stuff, like the kettle’s stopped working, or something daft like that’

Participant C7, Front-line

Part of the issue revolved around the system in place for distributing incident alerts, as participants described either receiving too many or too few. The irrelevant incident alerts that participants spoke about usually related to things that were viewed as inconsequential. Five participants spoke about how experienced workers differed to people who had just started working. As more time was spent in a dangerous location then the risks became normalised:

‘It’s a dangerous place. Sometimes the danger isn’t in the actual process or the chemistry of everything, it’s about the simple day-to-day tasks that people just switch off to. Because it’s so easy you can do it with your eyes shut. Yeah and that’s what catches people out most of these time.’

Participant C3, Front-line

In environments with potentially deadly hazards, incidents that could happen in any workplace could seem inconsequential and irrelevant. After ‘priority versus priority’, Table 38 shows that the category of coding most frequently used for the second contradiction was ‘self versus human nature’. Many of these references were related to the process of risk normalisation that changed how relevant workers thought risks were to their own work. However, there was an additional dimension to the category. Participants on the one hand described their own attitudes to safety as extremely professional and active, meaning that similar incidents to those in the alerts were unlikely to occur. Moreover, workers had faith that their procedures would protect them, again rendering the incident irrelevant:
‘Or it’s maybe a fairly new type of incident that’s never been documented or investigated before and they’ve had to change working practices to prevent it happening again... That’s quite rare to be honest.’

Participant B7, Management

‘A lot of them have a lot of similarities. And thankfully that doesn’t happen in, on our refinery but it does at other refineries. And you think well, you haven’t really learnt from your mistakes as such. And maybe you should have done.’

Participant C11, Front-line

In contrast, the cause of incidents experienced by others was often also seen to be due the incompetence of the workers involved rather than the circumstances that they found themselves in:

‘Some things are tedious like somebody put a ladder over a dosh sheet on laminate flooring, so of course it’s going to slide like because obviously the ladder hadn’t, the ladder has rubber feet so obviously it needs friction, it needs contact with the flooring... But obviously, but obviously it was a bad accident but to me that’s just negligent.’

Participant B2, Front-line

[redacted]

‘Yeah it’s, not everything needs discussing because some of it is just somebody’s had a stupidity spasm or something like that.’

Participant C12, Front-line

If an incident alert is perceived to be on an irrelevant topic then regardless of how it is presented to workers for reflection it is unlikely to result in learning, as workers will not be motivated to learn. In the case of the second contradiction, the tools of the HSE department were insufficient
for ensuring that the right amount of relevant incident-information is distributed to teams. Risk normalisation and a tendency to attribute the incidents of others to lapses in judgement are universal across humans, and impact the perceived relevance of alerts. If alerts that are actually irrelevant are sent to workers due to the HSE department’s incorrect understanding of who needs to know what, then this reinforces the natural instinct of workers to dismiss alerts without actively thinking on their implications. Tools are needed to both ensure relevant information is sent to where it is needed, and to help workers overcome instinctual heuristics that prevent them from reflecting on incident alerts.

**Contradiction 3: Inconsistent underpinning pedagogy**

**Description of the contradiction**

The third contradiction that arose from the data was a lack of consistent pedagogy that underpinned attempts to support workers in their reflection on incidents, in other words, an inconsistent implementation of how learning theories were used to support learning. This was exhibited in the learning of both organisations and individuals. From the perspective of organisational learning, the objectives of the LFI process related to making changes. However, new incidents made the recommendations from previous incidents less of a priority. Thus, the organisational learning could at times stay relatively superficial, as easier actions were completed without addressing more fundamental issues before a new incident occurred with a new set of recommendations. The lack of anybody with the responsibility to evaluate changes made was also spoken about.

From the perspective of individual learning there were examples of team supervisors actively engaging their team in learning using incident-information. However, pedagogical practice of team supervisors was inconsistent across and within organisations, as no training was provided to equip facilitators with the skills needed for success in their duties. This was compounded by an incident occurring being the trigger for learning. Information was often only presented once, usually at a time when it had no direct connection to the work being conducted that day. Additionally, prior research has demonstrated that learning is best interspaced, i.e., over a period of time, and involves small tests of understanding (Dunlosky, Rawson, Marsh, Nathan, & Willingham, 2013). While some team supervisors did return to incident alerts and tested the understanding of their workers, many participants described passively watching presentations. The tools of the activity system were insufficient to support good pedagogical practice and enable effective learning.
Figure 33 shows the division of labour in tension with learning objectives. In addition, the figure shows that tools fail to support team supervisors in their role as a facilitator, again leading to a tension with learning objectives.

![Figure 33 Insufficient pedagogical tools and division of labour lead to tension with objectives](image)

**Discursive manifestations of contradiction 3**

Table 39 shows the distribution of the versus codes related to the third contradiction, inconsistent pedagogy.

<table>
<thead>
<tr>
<th>Versus code</th>
<th>Reference count</th>
</tr>
</thead>
<tbody>
<tr>
<td>Priority vs priority</td>
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</tr>
<tr>
<td>Self vs human nature</td>
<td>19</td>
</tr>
<tr>
<td>Self vs others</td>
<td>32</td>
</tr>
<tr>
<td>Self vs self</td>
<td>12</td>
</tr>
<tr>
<td>Self vs situation</td>
<td>22</td>
</tr>
<tr>
<td>Self vs system</td>
<td>49</td>
</tr>
</tbody>
</table>

215
The ‘priority versus priority’ and ‘self versus system’ codes that were associated with the third
contradiction focused on issues implementing the LFI process. Participants described how the
need to implement and then evaluate recommendations following incidents were often
neglected, as other incidents pushed different actions to be top priorities. As ensuring
recommendations were followed through was not the responsibility of any particular department,
and the incident reporting system did not provide any support in prioritising actions of multiple
incidents, this was described as an unstructured part of the LFI system. [redacted]

‘But I think sometimes you know another email arrives that we’ve had another incident of
a similar nature or there’s been, or there’s been no change in the reduction in those sort of
incidents. Then we revisit it and re-brief it but generally that’s a one-off safety brief.’

Participant B8, Front-line

Other studies have demonstrated that organisations tend to implement recommendations that
are easy to achieve but do not address the underlying issues that would reduce the number of
incidents (Lundberg et al., 2010; Stackhouse & Stewart, 2017).

The codes across the ‘priority versus priority’ and ‘self versus system’ categories focused on
learning at the individual level, and how an incident alert was used by team supervisors to
support learning. In general, there was inconsistency across teams in how supervisors led
discussions on incidents during meetings. [redacted]

Despite this, some participants noted that their team supervisors presented information in a dry
and un-interactive fashion that was not conducive to learning:

‘While the general format is, the manager will stand there and I’d say read directly off a
slide on a screen and then say right I just gave you that brief... Not that there is any
understanding there.’

Participant B5, Front-line
Several participants also mentioned the difficulty in creating presentations with high-quality content. The presentations were described as needing to contain enough details to understand the content, but not too many details to lose the interest of those listening:

‘You need to fully understand it as well, it can’t just be a surface one that says, “Oh, they’ve had a fire at-.” You need to know the why’s and the where’s of those, don’t you? And again, that’s better if it’s distilled into simple language, which again, is where we struggle a bit.’

Participant C16, Management

While the primary tools used to distribute incident-information at all three organisations were one-off emails and presentations, participants commented that passive means of distributing information were often insufficient to enable learning. These issues were often raised in the ‘self versus self’ category as the content that was being discussed went against the beliefs of the workers, or because openly sharing experiences was uncomfortable:

[redacted]

‘I mean it’s a little bit embarrassing at first, but when you get through that it’s alright.’

Participant C2, Front-line

Another issue that arose was that information on an incident was only presented once to workers. One participant mentioned that they felt it would be better if incidents were revisited after the initial discussion to see if people remembered what had been spoken about:

‘I think if they done a follow up, and to be fair, this is something that’s in my own power to do, so I could do this on my own back. But if after 2 months or 3 months at a team meeting I get all the guys in and we go OK, this is the mandatory brief we done in January, here’s a couple of questions on it. Let’s see if you still remember that and if you’ve taken it onboard at the time or not.’
Contradiction 4: Causality of incidents

Description of the Contradiction

Incidents are highly influenced by probability. On the one hand, an organisation can have the highest standards, work safely, and be constantly learning but still fall prey to unfortunate circumstances that lead to a series of incidents. On the other hand, due to probability it is possible for an organisation to work in an unsafe manner but experience no incidents. Probability is perceived as luck. This dependency on probability means that the number of incidents is a potentially misleading measure of either safety or learning. Consequently, it is difficult for either an individual, a team, or an organisation to know whether they are achieving their LFI objectives.

This contradiction could be seen as a tension in the activity system caused by not having the tools to assess how successfully objectives are being met. However, there is a more fundamental tension that follows from the first contradiction identified in this analysis: the objectives of the activity system are not clear to the subjects. Chapter 6 demonstrated that on a subconscious level most members of the LFI activity system were striving towards the same general objectives, and everyone was unified behind the same system output. However, as these objectives remain tacit there were no elements of the system which were purposefully crafted to feedback to the subjects and community how well the objectives were being achieved. This tension between subjects and objectives is depicted in Figure 34.
Discursive manifestations of contradiction 4
As can be seen from Table 40, the fourth contradiction, concerning the probabilistic nature of incidents, had the least discursive manifestations of the four. The only category which had a large number of references was ‘self versus situation’.

Table 40 Discursive manifestations of contradiction 4

<table>
<thead>
<tr>
<th>Versus code</th>
<th>Reference count</th>
</tr>
</thead>
<tbody>
<tr>
<td>Priority vs priority</td>
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</tr>
<tr>
<td>Self vs human nature</td>
<td>19</td>
</tr>
<tr>
<td>Self vs others</td>
<td>8</td>
</tr>
<tr>
<td>Self vs self</td>
<td>11</td>
</tr>
<tr>
<td>Self vs situation</td>
<td>62</td>
</tr>
<tr>
<td>Self vs system</td>
<td>5</td>
</tr>
</tbody>
</table>

The ‘self versus situation’ code was applied multiple times for this contradiction for a variety of reasons. Participants spoke about the catch-22 situation of needing an incident to initiate learning.
which would hopefully reduce the number of incidents. Although if this goal was achieved there would then be fewer opportunities to learn:

[redacted]

’So unfortunately, they don’t know that they’re not understanding it or taking on the best practice until it results in something that you didn’t want to happen.’

Participant B7, Management

‘You’d be, and the less incidents you get, so the less incidents you’re getting reported, you know the less likely you are to improve I think.’

Participant C16, Management

Participants also described difficulty in understanding how they were performing due to the uncertain nature of incidents.

[redacted]

A participant in Company C described a similar situation:

‘I don’t know. Because at the time I thought we had a pretty robust system. So when something happens like that it always takes you back a bit. Especially in the way it happened and to the degree it happened, it was a bit of a shock on the refinery. And people started questioning themselves a lot, if I, if that had been me what would I have done in that situation? Could it have happened to me?’

Participant C9, Management
In all three organisations audits were used to assess how safely work was being conducted. One participant from Company B commented on how this still left many opportunities for people to unknowingly be conducting their work incorrectly:

‘If he doesn’t pick me up on that I could then be going out to the next job and not do what he’s looking for, and then I wouldn’t be picked up again for another 6 months’

Participant B1, Management

A participant in Company C described a similar situation:

‘You look at them and it's like we've never had an accident like that. Now is that because, because we're talking about them and finding them? Or is the system not really finding the problems we've got? I don't know which way. I don't know how to interpret that.’

Participant C9, Management

In response to the interview prompt ‘how can your company know if they are learning from incidents?’ many respondents found producing an answer difficult. Several mused that whether incidents were going up or down would give some indication, but that it was in fact very difficult to know with any certainty:

[redacted]

‘From a reduction in work based accidents. But Company B doesn’t, never had a high accident at work rate any way. But yeah, I don’t know.’

Participant B2, Front-line

An incident appeared to cause a crisis of identity where participants were unsure of whether they had been working at a high standard or had just been lucky. While the number of incidents experienced by an organisation is the ultimate target, it was seen as unsuitable as a
7.4 Discussion

Chapter 7 presented a mixed methods analysis of both the enablers and barriers to learning in LFI to address RQ3a and RQ3b. By comparing three organisations using both quantitative and qualitative methods beneficial practices that were unique to each organisation could be highlighted. Furthermore, four contradictions that could create barriers to learning were identified. The fact that the same contradictions were identified across three different cases lends to their generalisability to other organisations in the energy sector (Suri, 2011; Yin, 2013).

The results of the LFIQ highlighted that reporting appeared to be an area of strength for all organisations, and contextualising and disseminating incident-information appeared to be more challenging. Descriptions of each organisation’s activity systems were constructed using analysis from Chapters 5 and 6 and then returning to the interview data for additional information. Through exploration of the activity system description enablers of learning were identified. Some themes that emerged on the enablers of learning are discussed in more detail below. Additionally, exploration of discursive manifestations of contradiction in the interview data led to the identification of four underlying issues in the LFI activity systems of energy organisations. These issues would create barriers to learning and are also discussed in more detail below.

7.4.1 Enablers of LFI

Use of technology

In all three organisations technology was used to disseminate information. This involved the use of email, but also databases, which have been the focus of the majority of studies to investigate networked learning in LFI (e.g., J. G. Anderson et al., 2010; Jacobsson et al., 2010). Nonetheless, the difficulties associated with Company B’s engineers working remotely appeared to spur some
additional innovative use of technology to enable the LFI process. One example of this was the use of a digital platform to provide relevant information on potential equipment faults and location history to engineers just before they conducted a task. Information on specific incidents was not provided to engineers, but this could be an area for future development.

Social media was also employed by the engineers at Company B. WhatsApp is a platform that prior research has found enables adults to learn as it is familiar to them (Madge et al., 2019). However, the official platform supported by Company B, Yammer, was infrequently mentioned by participants. Of the two participants who did mentioned Yammer both admitted to being infrequent users. Attempts to use technology to enable learning are common in professional settings, but are usually only effective when integrated into daily practices (Billett, 2002). WhatsApp holds the advantage over Yammer of being a popular social media platform that most workers would naturally check over the course of their day (Conole & Alevizou, 2010).

Informal exchanges have been highlighted in the literature on LFI as important to supplement the formal distribution of incident-information (Lukic et al., 2012; Murphy et al., 2018b; Vastveit et al., 2015), and links between groups have been shown to be associated with successful LFI (Gressgårđ & Hansen, 2015). Social media, or other technologies that support informal communication across geographic distances, could be an important avenue to explore in enabling informal LFI exchanges. The lowest rated items of all three organisations on the LFIQ related to communication. Through the detailed descriptions of each organisation it appeared that all had a multitude of communication platforms that supported information dissemination and information gathering. However, only Company B had tools that would support informal exchanges. Although, as their teams worked in the same location, Company C would not need social media to share incident-information within a team, it could be an effective medium for sharing between shifts, creating a record of discussions, or incorporating multi-media, such as videos.

Another advantage of the technology employed by Company B was the ability of the digital platform to react to the tasks that engineers were about to undertake, providing information on equipment or procedural changes. The platform did, nonetheless, not go as far as providing information on incidents. In workplaces the majority of learning occurs through practice and enactment of tasks (Billett, 2004; Tynjälä, 2008). In order to be meaningful incident-information must therefore be understood in terms of a person’s own work context (Weick et al., 2005). Technology that can provide incident alerts to workers just before carrying out relevant work would therefore be an incredibly useful addition to organisations’ LFI tools.
Contextualising incident-information

Contextualising incident-information has been raised in the literature as a challenge in LFI (Margaryan et al., 2018). Prior research has suggested that part of this issue is that not enough time is allocated to reflection in incident-information (Drupsteen & Hasle, 2014; Lukic, 2012). However, two of the top five highest rated items of Company A’s LFIQ results related to contextualisation. [redacted]. [redacted] embedding incident-information into regular training programmes was also mentioned. The most explicit description of this was in Company C, where one participant spoke of how incidents were discussed in the orientation of new workers to help them understand why procedures contained certain steps.

Besides sufficient time allocation, one issue that has been discussed with relation to contextualising in LFI is a lack of tools to support workers in contextualising incident-information (Margaryan et al., 2018). Participants in this thesis appeared to contextualise incidents in three different ways: reflection on incident-information when alone, discussion with colleagues, and through encountering unexpected situations. Information repositories, both of incidents and supporting documents such as procedures and personal protective equipment, provided individuals with the ability to find information and reflect upon it. The same repositories also became resources that could be consulted by workers when encountering unexpected situations. Finally, as discussed in Chapter 5, people’s networks became both scheduled and spontaneous resources for discussing incidents to contextualise them. Networks also provided an alternative route for gathering information to the formal databases.

While tools existed within each organisation to locate information when needed, none of the tools provided any support for regulation of engaging with incident-information. In dynamic environments regulation of learning is needed to scaffold knowledge development (Fontana, Milligan, Littlejohn, & Margaryan, 2015). In the case of LFI, discussion through groups is likely to provide some regulation of activity (Hadwin et al., 2011). Nevertheless, digital tools could be created to better aid regulation of LFI outside of group meetings to aid the contextualisation of incident-information by self-reflection or encountering unexpected situations. This has proven to be an effective strategy in other learning processes (Murphy, Coiro, & Kiili, 2019; M. Zhang & Quintana, 2012).

7.4.2 Barriers to LFI

Communicating incident alerts

The results of the LFIQ highlighted that dissemination was a potential issue, as it was rated as the lowest scoring phase of the LFI process for all organisations. When examining the lowest rated
items from the LFIQ for each organisation at least two of the bottom five items for each organisation related to dissemination. Several questions related to contextualisation also appeared in the lowest rated items, revolving around effectively ensuring that the right people received the right information. This is similar to the findings of Chapter 5 that showed that information was generally communicated from the top of the organisation down, without necessarily providing any pathways for providing feedback. As seen in Table 2 in Section 2.3.2 these results resonated with some of the studies that have previously looked at the barriers to effective learning in the LFI system: Lukic (2012) found that front-line workers felt they did not receive feedback on their thoughts on incidents, while Drupsteen and Hasle’s (2014) focus group participants complained about a lack of agency in the LFI process.

However, the four contradictions that surfaced using activity theory suggested that the issues experienced by organisations in their LFI processes were more complex that a lack of communication pathways. Safety and learning are often compatible but differ in several ways (Littlejohn et al., 2014). The intended output of the LFI process is to reduce incidents, in line with the ideas of safety (Hollnagel, 2014), and this should be accomplished by learning from past incidents (Lindberg et al., 2010). Nevertheless, the tools employed by organisations in the LFI process have been designed without underlying theories of learning at their core. Information is distributed in the form of emails and presentations. However, reading or hearing information once is often not enough for individuals to be able to recall that information at a later date (Dunlosky et al., 2013). Furthermore, in order to improve safety, procedures and technology was updated to engineer out the need for human judgement. As workers learn through conducting their daily tasks, these changes reduced the need for workers to have underpinning knowledge of their jobs and impacted their daily learning (Billett, 2002, 2014).

The second and third contradiction concerned workers actively engaging with the information that they saw. Although some team supervisors naturally tried to ask provocative questions there was a lack of training on pedagogically effective facilitation techniques. A combination of receiving genuinely irrelevant information and natural cognitive biases towards perceiving the incidents of others as irrelevant meant that effective pedagogical techniques were required for workers to engage with incident-information.

As the objectives of the LFI system remain tacit and unstated there was a natural confusion that caused the tools of the activity system to be designed with only the end goal in mind: reducing the number of accidents. If the LFI system is to truly transform, then it must consider how it supports the learning of individuals, using educational research and theories to design its tools. Although they exist in very different contexts, educational platforms can provide
intelligent and scalable systems to provide personalised recommendations (Littlejohn & Hood, 2018; Schumacher & Ifenthaler, 2018).

Do I feel lucky?
While the first three contradictions that emerged in the activity theory analysis are similar to barriers that have been identified in LFI before, the fourth is unique in the literature on LFI. While it is acknowledged in models of safety that probability has a role in whether an incident occurs or not (Reason, 2000), how this would affect learning following an incident has not been considered in the literature. The participants in this thesis described themselves as being in a paradoxical situation where they believed themselves to be doing well unless an incident occurred, at which point they questioned whether they had really been doing well. This change of perspective is closely connected to ideas of identity and agency.

Workers tied their identity, i.e., their inner values and beliefs (Eteläpelto et al., 2014), to the presence or absence of incidents. When an incident occurred, workers had a crisis of identity as they no longer understood how safely they conducted their work. As safety and learning were intermingled in the minds of participants this consequently would have an impact on how they thought of themselves as learners. Without a clear image of where their strengths and weaknesses lay, a worker would also likely suffer from a lack of agency, as they could not be sure of the cause of events (Eteläpelto et al., 2013).

One area of debate in literature on safety is the definition of safety as an absence of undesirable events (Hollnagel, 2014). A so called ‘safety-II’ perspective has been promoted, where safety is considered not by an absence of negative consequences, but by the active ability to adjust to unexpected circumstances (M. A. Sujan et al., 2016). This definition of safety is far more compatible with the idea of learning and developing. Rather than relying on the number of incidents that has occurred this view of safety encourages understanding process- and environment-related measures, such as the ability to communicate effectively and openly, to be taken into consideration to evaluate safety. Positive examples of avoiding incidents could also become opportunities to learn, something that has been raised as missed opportunities currently by the majority of energy organisations (Sanne, 2012). In terms of the implications for learner identity this definition of incidents also does not rest the entire assessment of a person’s ability to act safely on events that are at least partly often down to chance. With a more holistic understanding of how dynamically organisations, teams, networks, and individuals can react to unexpected situations, the impact to a person’s feelings of identity and agency is likely to be reduced when an incident does occur.
7.4.3 Limitations

While every effort was made to ensure the rigour of the analysis conducted in this chapter there remain several limitations. The most significant limitation relates to the use of activity theory-based analysis. The identification of contradictions is a subjective process, which was one reason for the inclusion of the LFIQ as a more objective measure of where participants perceived strengths and weaknesses in their organisation’s LFI system. Data collection methods also relied solely on interviews for qualitative data. Future studies would benefit from the inclusion of participant observation and ethnographic methods to validate insights from the interviews conducted in this thesis.

Another area for future expansion would be to introduce interventional methods such as the Change Laboratory (Engeström et al., 1996). Activity theory is concerned with the historical development of activity systems. While some historical aspects were included in this analysis, they predominantly related to how the LFI process induced change, rather than how it has itself changed. Methods such as the Change Laboratory are more effective than single interviews in capturing the historical evolution of an activity system. It would also provide an opportunity to contrast my deductions as an educational researcher on beneficial directions for organisations LFI systems to strive towards, with the ideas of practitioners.

7.4.4 Summary

Chapter 5 addressed a well-established gap in research on LFI related to the nature of networks in this context. The methods used in Chapter 5, however, have been critiqued for their inability to incorporate cultural context. Chapter 6 therefore began to build a picture of the culture of the three organisations by exploring what participants sought to achieve through the LFI process. Chapter 7 brought the results of both Chapter 5 and 6 together in a holistic manner and, built upon them to create an understanding of enablers of inhibitors of learning in the context of LFI. Chapter 8 will now discuss the contributions of this thesis to knowledge and discuss areas for future development.
8 Discussion and Conclusions

Chapters 1 and 2 of this thesis provided an overview of research connected to learning from incidents (LFI) and learning, including highlighting critical gaps. Chapters 3 and 4 then discussed theoretical and methodological considerations and outlined the research design of this thesis. Finally, Chapters 5 - 7 reported the results of analysis undertaken to address the gaps outlined in Chapters 1 and 2. Discussion in relation to the analysis, research questions, and broader landscape of literature was included at the end of Chapters 5 - 7. This final chapter, Chapter 8, summarises and extends the insights of the results of the analysis in Chapter 5 - 7, including identification of areas that are still in need of further exploration.

8.1 Aims and Contributions of the Thesis

As thousands die globally in workplace related incidents each year (National census of fatal occupational injuries in 2017, 2018; Workplace fatal injuries in Great Britain, 2019, 2019), organisations, especially in high-risk domains such as the energy sector, have a moral imperative to improve the safety of their workers. One tool for improving safety is LFI, in other words, analysing unexpected events in the past to prevent incidents in the future (Drupsteen & Guldenmund, 2014). The phases of the LFI process, as described by Drupsteen et al., (2013) and Littlejohn et al. (2017), are shown in Figure 35 along with where the research questions of this thesis fit within this process.

Research to date has focused on the earlier phases of the LFI process, such as barriers to reporting (Haw et al., 2014) or analysis techniques (Lundberg et al., 2009). This thesis began with the aim to address a specific gap in highlighted in multiple literature reviews: a dearth of understanding on
how information on incidents is communicated (Drupsteen & Guldenmund, 2014; Lindberg et al., 2010). This gap led to the first research question of the thesis:

**RQ1**: How are networks used in LFI? (Chapter 5)

However, while descriptions of the structure and role that networks play give some insight into communication in LFI, the desired outcome of LFI is to improve the safety of workers. In order to understand how networks, and the communication that happens within them, contribute to LFI, the wider cultural context that the networks exist within must be explored (Scott, 2012). The most important cultural consideration is the perceived objectives of a particular activity, as these objectives will drive the actions of individuals (Nardi, 1996). However, while the literature on LFI agrees that the outcome of LFI should be a reduction in the number of incidents, and that this outcome should be achieved by learning, what learning entails and concretely means to practitioners remained a gap in the conceptualisation of LFI (Margaryan et al., 2017). So, the second research question addressed in this thesis was:

**RQ2**: What do workers perceive as successful learning in the context of LFI? (Chapter 6)

Understanding the objectives of LFI (i.e., what practitioners perceived as successful learning and hence were working towards) began to unpack how networks contributed to LFI. However, networks are not the only aspect of LFI that would determine whether learning occurred. RQ3a and RQ3b thus focused on a holistic examination of organisational systems supporting LFI, identifying both beneficial practices that other could learn from, and fundamental contradictions in the system that would create barriers to learn:

**RQ3a**: What beneficial practices in LFI enable learning? (Chapter 7)

**RQ3b**: What barriers to learning exist in the LFI process? (Chapter 7)

RQ3a and RQ3b aimed to add to previous studies that had either presented case studies of organisations that learnt well from incidents (Vastveit et al., 2017) or barriers to successful LFI
(Drupsteen & Hasle, 2014) with the aid of explicit success criteria generated in response to RQ2. With these questions and gaps in mind, the contribution of this thesis to theoretical knowledge can be summarised as:

- A detailed understanding of the different types of network activities that exist within LFI
- A taxonomy breaking down what practitioners conceptualise as successful learning
- Examples of beneficial practices in LFI
- Identification of fundamental contradictions that make current LFI systems unsuitable for enabling successful learning

Furthermore, the methodology employed in this thesis contributes several innovations to thematic analysis and activity theory. These theoretical and methodological contributions are discussed in detail in Section 8.2. Key findings are presented first as bullet points, before a detailed description summarises how these results were generated and how they relate to existing literature.

### 8.2 Contributions to Knowledge

#### 8.2.1 Theoretical Contributions

**The role of networks in learning from incidents**

RQ1: How are networks used in LFI?

- The network structure is influenced by the geographical spread of the organisation, and the number of opportunities for workers to interact with other groups, e.g., at inter-departmental meetings.
- Networks are involved in both the communication and contextualisation phase of the LFI process.
- Networks support formal distribution of incident-information, but also facilitate gathering and sharing of incident-information, experiences, and concerns.

RQ1 was addressed using mixed methods SNA. Initially network-level analysis of front-line teams was conducted using quantitative data from a social network survey. This analysis showed that the teams of Company C were densely connected. In this organisation the informal advice-seeking network showed no central actors, but the team supervisor appeared to be the main source of formal information on incidents. In Company B both the informal advice-seeking and the formal
information-receiving networks were centred around key individuals who possessed formal roles in the team, such as team supervisor or coach. Subsequent qualitative analysis suggested that this was due to team members being geographical far from each other. In Company C advice would be asked from whoever was physically close to them, before raising concerns with a team supervisor. In Company B, as there were no team members close, a worker would immediately contact an authority for advice. In all three organisations the team supervisor was the primary way in which incident-information would formally enter the team.

Analysis at the ego-level, i.e., looking at individuals, identified that managerial level employees had larger and more diverse networks than front-line workers. As their connections were predominantly with people in their own team, front-line workers were highly dependent on their team supervisors to hear about incidents. Managerial workers, conversely, had access to a variety of sources of information, and in the qualitative analysis several examples were given of discovering novel information on incidents at events, such as at conferences or meetings of professional organisations. Although the same general pattern was seen in Company C the front-line workers in that organisation had larger and more diverse networks than in Company B. Details that surfaced in the qualitative analysis suggested that this was due to team members participating in a variety of inter-disciplinary meetings. Company C front-line workers would therefore be less reliant on their team supervisor to receive information.

The qualitative aspect of the SNA not only provided some explanations for the patterns observed in the quantitative data, but highlighted that networks were important for information distribution of incident alerts and for contextualising information. Workers contextualised information on incidents through discussion with colleagues, but also by using their connections to find out additional information needed to understand how an incident related to their own work. Furthermore, when unexpected situations arose workers would use incident-information to try and reflect on what was happening, either through discussing the situation with colleagues or by consulting a database of incidents.

Considering the 3-P model of workplace learning, the study of networks in this research relates predominantly to the learning process (Tynjälä, 2013): how are workers using their networks in activities for learning? The results of Chapter 5’s analysis suggested that networks are primarily used for information-dissemination activities and for contextualising. In the inductively generated categories I suggested that there was information-dissemination, information-gathering, and information sharing activities occurring. These different activities all involved the exchange of information between workers, differing in the direction of information flow, how formal and structured the activities were, and how conscious the exchange of information was.
Although information-exchange is not in itself learning, as information must be reflected upon (Dewey, 1910), the differences that arose in the different kinds of information-exchange activities closely resembled the dimensions of informal learning suggested by Eraut (2000, 2004). Table 41 contains a modification of Eraut’s informal learning dimensions for information-exchange. Vastveit et al. (2015) provided examples of informal learning exchanges supporting LFI in energy organisations. Gressgård and Hansen (2015) evidenced the benefit of good relationship influencing information-exchange between groups and subsequently how well LFI was perceived to occur. Informal networks play an important role in LFI. The typology developed in this thesis is an important step in enabling both practitioners and researchers to reflect and evaluate how both formal and informal networks are contributing to information-exchange.

<table>
<thead>
<tr>
<th>Dimension</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Formality</td>
<td>Does the information-exchange involve formal mechanisms, such as professional groups or meetings?</td>
</tr>
<tr>
<td>Direction of information flow</td>
<td>Is the information moving through hierarchal rankings in the organisation, such as from the top to the bottom, between peers, or some other combination?</td>
</tr>
<tr>
<td>Deliberativeness</td>
<td>Is the information being shared in a deliberate manner with the intention of supporting learning?</td>
</tr>
<tr>
<td>Reactivity</td>
<td>Is the information being shared in response to certain stimuli, such as an unexpected situation, or continuously in a regular manner?</td>
</tr>
<tr>
<td>Explicitness</td>
<td>Are learners aware that they are gaining information?</td>
</tr>
</tbody>
</table>

In the LFI process several researchers have highlighted that incident alerts should be developed and distributed intra- and inter-organisationally, enabling learning vicariously through the experiences of others (Drupsteen & Guldenmund, 2014; Lindberg et al., 2010; Margaryan et al., 2018). The type of information-exchange referred to in these articles tends to be formal, deliberate, explicit, in response to an incident, and from the top of the organisation (e.g., form the Health and Safety department) to the bottom. Due to its deliberate and explicit nature this is perhaps the most controllable form of information-exchange. However, when considered in light of the second use of networks in LFI that arose from the qualitative data, contextualising, and the
Participants described learning as most effectively happening through discussion. A wide range of studies have demonstrated the benefits of learning through discussion (Knight & Mercer, 2015; Mercer et al., 2004; Murphy et al., 2019), however, it has also been noted that productive discussion is not guaranteed without guidance (Häkkinen & Mäkitalo-Siegl, 2007). Moreover, discussion is aided by the presence of people with a variety of backgrounds who can draw on a wealth of different experiences (Hicks, 1996). One the one hand, the SNA structure showed that managerial level employees, with their diverse networks and connections, were likely to engage in beneficial dialogue. On the other hand, front-line teams were usually connected only to their team members, i.e., people who were likely to share a similar background to themselves. In addition, the front-line team workers were mostly dependent on their team supervisor for the introduction of incident-information. How well they could contextualise the incident alerts that they received would therefore be dependent upon the availability and guidance of their supervisor, although the analysis conducted in Chapter 7 found inconsistency in the pedagogical approach of team supervisors. This is similar to other findings in the literature that show discussions on incidents vary greatly depending on the skill of the facilitator (J. E. Anderson & Kodate, 2015; Nicolini et al., 2011b). Reiter-Palmon et al. (2015) demonstrated that conversations during the investigation stage of LFI could be scaffolded using a report form. A similar approach to scaffolding conversations in the contextualising phase of LFI could be beneficial.

Furthermore, studies have shown that tools used for inter-organisational incident-information-exchange, i.e., databases are usually too sparse on details to enable learning (J. G. Anderson et al., 2010; Jacobsson et al., 2009, 2010). With more appropriate scaffolding these databases could become a digital dialogic space (Wegerif, 2015). The analysis in this thesis showed that managerial-level workers already had a relatively diverse and wide network. Moving away from databases as an area to merely report the basic facts of an incident to zones of conversation would further increase the reach and information-gathering abilities of management. In addition, as the discussions on the forums could even be anonymous, dialogue could be achieved without too much of a strain on resources, which is usually a downside to expanding a network size (Hakkarainen et al., 2004).

The analysis of Chapter 5 began to unpack how networks are used in LFI. However, due to the limitations of SNA the networks needed to be placed in a cultural context before their impact could be considered holistically (Borgatti et al., 2009). The first step in this was unpacking what
was perceived to be the objective of LFI, in other words, what participants believed to be successful learning in the context of LFI.

Perceptions of successful learning

RQ2: What do workers perceive as successful learning in the context of LFI?

- 24 different potential indicators of successful learning were identified.
- There was great variety among participants, but no significant evidence of a difference in perception between front-line and managerial participants.

A thematic analysis was conducted to explore RQ2. The thematic analysis initially inductively generated codes that represented either what participants described as a desirable outcome from LFI, i.e., a learning product, or something that was necessary for the learning process. These codes were then deductively mapped against the 3-P model of workplace learning. To aid understanding for a non-academic audience the language of the 3-P model was updated yielding four overarching themes: product, process, learner characteristics, learning environment.

Magnitude coding was applied at the source level, in other words each interview was labelled with a 1 if a code had been mentioned during their interview and a 0 was applied if they had not mentioned a code. Within each group there appeared to be a substantial diversity of opinions on what constituted learning. Together the 24 codes were considered a taxonomy of learning objectives, summarised in Table 48.
Table 42 Taxonomy of learning objectives of LFI

<table>
<thead>
<tr>
<th>Theme</th>
<th>Learning objective</th>
</tr>
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<tbody>
<tr>
<td>Learning Environment</td>
<td>Transparency</td>
</tr>
<tr>
<td></td>
<td>Formal communication pathways</td>
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<tr>
<td></td>
<td>Impromptu communication</td>
</tr>
<tr>
<td></td>
<td>Safety as an organisational value</td>
</tr>
<tr>
<td></td>
<td>Company strategy reacts to incidents</td>
</tr>
<tr>
<td></td>
<td>Organisational memory</td>
</tr>
<tr>
<td>Learner characteristics</td>
<td>Motivation to learn</td>
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<tr>
<td></td>
<td>Locative knowledge</td>
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<tr>
<td></td>
<td>Risk perception</td>
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<tr>
<td></td>
<td>Safety mindset</td>
</tr>
<tr>
<td>Process</td>
<td>Communication openness</td>
</tr>
<tr>
<td></td>
<td>Information quality</td>
</tr>
<tr>
<td></td>
<td>Evaluation</td>
</tr>
<tr>
<td></td>
<td>Monitoring</td>
</tr>
<tr>
<td></td>
<td>Impactful delivery</td>
</tr>
<tr>
<td>Product</td>
<td>Updated best practice</td>
</tr>
<tr>
<td></td>
<td>Updated official procedures</td>
</tr>
<tr>
<td></td>
<td>Updated technology</td>
</tr>
<tr>
<td></td>
<td>Additional safety barriers</td>
</tr>
<tr>
<td></td>
<td>Improved procedural knowledge and skills</td>
</tr>
<tr>
<td></td>
<td>Improved risk knowledge</td>
</tr>
<tr>
<td></td>
<td>No repeated incidents</td>
</tr>
<tr>
<td></td>
<td>Fewer incidents</td>
</tr>
<tr>
<td></td>
<td>Incident report numbers changing</td>
</tr>
</tbody>
</table>

Most of the different learning objectives in the taxonomy had parallels to indicators that had been investigated in prior research on LFI. For example, in the ‘learning environment’ theme, the objectives of ‘formal communication pathways’, ‘impromptu communication’, and ‘organisational memory’ have all been discussed in relation to LFI (Braut & Njå, 2013; Gartmeier et al., 2017; Gressgård & Hansen, 2015; Jacobsson et al., 2012; Lukic et al., 2012; Rossignol, 2015; Vastveit et al., 2015). ‘Safety as an organisational value’ and ‘transparency’ have to varying
degrees been discussed in literature on LFI, but are likely, along with the ‘open communication’ objective under the ‘process’ theme, to relate to a construct that has proven to be a key concept in learning: psychological safety (Edmondson, 1999; Leicher et al., 2013; Leroy et al., 2012). The final objective in the ‘learning environment’ theme related to organisations modifying their strategies based on incidents. This objective would include some elements that had been discussed in LFI literature, such as updating procedures (Littlejohn et al., 2017) and monitoring incident cause trends (Jacobsson et al., 2011), but also includes organisations allocating resources in response to incident.

The ‘learner characteristics’ theme, similarly to the ‘learning environment’ theme, contained objectives that had been discussed previously in LFI literature: ‘motivation to learn’, and ‘locative knowledge’. ‘Motivation to learn’ could be linked to whether workers perceived an incident as an opportunity to learn (Bauer & Mulder, 2011; Leicher et al., 2013; Rossignol, 2015) or whether workers felt they had agency to contribute to the LFI process (Lukic et al., 2013). ‘Locative knowledge’, i.e., knowledge on where to find information and resources, was specifically mentioned as part of Lukic et al.’s (2012, 2010) LFI framework. ‘Risk perception’ was an objective that had been discussed to an extent in the LFI literature. However, as with ‘company strategy reacts to incidents’, only part of what this code had been acknowledged. Perceived risk have been demonstrated to influence whether a worker reported an incident (Gilbey et al., 2016), however participants described incident alerts as reminders of how the hazards of their work environment. An accurate perception of hazards is important as it will influence how a worker connects incident-information to their own work (Weick et al., 2005). If an incident is understood to be relatively unlikely to occur due to the hazard involved being normalised, then that incident is easier to dismiss as irrelevant. The final objective of ‘learner characteristics’ was a ‘safety mindset’. To the best of my knowledge, ‘safety mindset’ is a novel concept in the context of LFI. As safety and learning are often complementary but differ in some respects (Littlejohn et al., 2014), it would be beneficial to further investigate how an individual’s orientation to safety impacts their learning.

The learning objectives ‘monitoring’ and ‘evaluation’ resonated with the final stage of Drupsteen et al.’s (2013) LFI model. With regards to the ‘process’ theme, ‘impactful delivery’ and ‘information quality’ were mainly described by participants in relation to formal LFI activities, such as team discussions. As has been observed in prior research, the impact and quality of formal LFI learning activities can vary greatly depending upon factors such as organisational support and facilitator skill (J. E. Anderson & Kodate, 2015; Nicolini et al., 2011a, 2011b; Reiter-Palmon et al., 2015). However, research into LFI learning activities has predominantly focused on incident-investigations or how what strategies an individual might employ to reflect on an incident they
were involved in (Bauer & Mulder, 2007). More research is needed to describe the learning activities engaged in by teams with an incident alert.

Most of the objectives under the ‘product’ theme related to either a change in behaviour or process (Littlejohn et al., 2017), or a reduction in the number of incidents. Participants also discussed the acquisition of different kinds of knowledge, related to either risks or procedures, as a goal of LFI. However, workers often did not feel that the newly acquired knowledge should affect daily practice, rather enabling workers to make more informed decisions when an unexpected situation arose, similar to the concept of adaptive expertise (Carbonell et al., 2014).

Some differences between organisations and roles could be attributed to the circumstances of a group. For example, workers in Company B mentioned locative knowledge due to the distributed nature of the job; engineers in Company B would have to rely on knowing where to find information rather than asking someone nearby for a second opinion. Fisher’s exact test was used to evaluate in each organisation whether there was evidence of a difference in the perceptions of front-line workers and management, which would indicate a difference in learning objectives and that front-line and management would need to be treated as separate activity systems in Chapter 7. No significant evidence was found of a difference in perceived learning objectives.

Research to date has conceptualised learning in an incomplete manner without comparing the ideas of researchers to the perceptions of workers, which are the actual driving forces of how LFI is implemented in workplaces. However, some objectives were far more commonly spoken about than others. Due to the limitations of thematic analysis it is unclear if each objective should be given an equal weighting in terms of importance. Further research must consider whether some objectives should be given priority over others.

While the analysis in Chapter 6 provided insight into the most important aspect of the culturally context of each of the case studies, it failed to consider each organisation’s system for LFI holistically. A holistic analysis of the LFI system of each organisation, drawing on the results of Chapters 5 and 6, was conducted in Chapter 7 to identify both enables and barriers to learning.

Beneficial practices in LFI

RQ3a: What beneficial practices in LFI enable learning?

- Reporting was the highest rated phase of LFI at all three organisations, supported by the incident reporting system tool.
- [redacted]
• Company B demonstrated innovative use of technology that supported both communication between isolated workers, and provided relevant incident-information to workers just before undertaking a task.

• Company C expanded the connections its front-line workers through a variety of different inter-departmental meetings. Additionally, Company C embedded incidents in their orientation material.

The strengths of each organisation’s LFI system were initially assessed using the LFIQ. For all three organisations reporting was identified as the highest rated phase of the LFI process. To date a large portion of the research that has taken place on LFI has focused on barriers to reporting incidents (Edmondson, 2004; Y Pfeiffer, Manser, & Wehner, 2010). The organisations in this thesis did not appear to suffer from many of the issues highlighted in research to date. As part of the selection criteria for taking part in this thesis was an established LFI system, the organisations could have benefited from the results of prior research thus creating a culture that would encourage reporting (Leroy et al., 2012). While several barriers to learning have been identified in LFI research (Drupsteen & Hasle, 2014; Lukic, 2012; Sanne, 2012), it would be beneficial to understand if different issues arise at different stages of development of the LFI system.

After analysing the results of the LFIQ a description of each organisation’s LFI system was created using the results of the SNA, the taxonomy of learning objectives, and additional details on the rules and tools of the systems from the interviews. [redacted].

Company B had developed strong technological tools to support LFI. [redacted], the digital platform used by Company B provided engineers with relevant information on potential equipment faults that they might encounter in the task they were about to conduct. This was necessary as the engineers in Company B had no control over which equipment was installed in a customer’s residence, and could not possibly remember every detail for every variation of the equipment. While the information provided did not extend to information on process related incidents, there was a section for tips on procedures.

From the viewpoint of learning the ‘just in time’ provision of information would have several strengths. Firstly, relating potential hazards to tasks rather than incidents would aid in connecting that information to procedures (Snowden, 2002). Secondly, if an unexpected situation arose, the information on potential incident faults could be recalled to reflect on a situation as it happened, helping to decide the best course of action (Biesta & Burbules, 2003). This would help hazard information to be delivered in an impactful manner, help hazard information be integrated into organisational memory, and improve workers knowledge of the reasoning behind
procedures. For Company B ‘we receive incident-information relevant to our work’ was one of the highest rated items of the LFIQ. Presenting incident-information in connection to processes, either through safety-oriented events or a digital platform, in addition to standalone incident alerts is likely one reason that workers felt the information that they were receiving was relevant.

In addition to the digital platform designed to support work, participants in Company B also described frequent use of the social media platform WhatsApp to contact others. WhatsApp allowed photos to be sent, so that coaches, team supervisors or other colleagues could get a better understanding of what an issue might be. WhatsApp not only provided functionality that mitigated some of the downsides of working at a distance, i.e., sharing visual artefacts, but it also enabled asynchronous communication. As there were strict rules governing phone use, this allowed safety engineers or coaches to provide advice even when they were not immediately available. Interestingly the social media platform introduced by the organisation, Yammer, was not used by workers. WhatsApp is one of the most popular social media platforms, and has been shown to be useful in workplace settings for distributing instructions (Johnston et al., 2015). WhatsApp has also been shown to be an effective tool for education as it allows learners to communicate and collaborate both synchronously and asynchronously (Conole & Alevizou, 2010).

Nonetheless, compared to other social media platforms such as Yammer and Facebook it does not contain many features of learning management systems (Meishar-Tal, Kurtz, & Pieterse, 2012). Compared to WhatsApp Yammer is not as widely used, meaning that workers would need to expend effort to learn how to use its interface. A platform like Facebook, which is widely used but has more affordances for learning than WhatsApp, could support LFI, offering additional avenues for both formal pathways of communication and impromptu communication.

The strength of Company C’s LFI system appeared to be in its division of labour. As discussed in the results of Chapter 5’s analysis, Company C appeared to create a lot of cross organisational meetings that enabled front-line workers to expand their network and discuss incident with those outside their own team. Not only did this allow them access to multiple perspectives on events, which is pedagogically beneficial for discussion (Hicks, 1996), but it reduced the reliance on the team supervisor as the only means by which incident-information entered the team. Integration of representatives from front-line teams into inter-organisational meetings is likely to be enable discussions that more fully engage with incidents, as participants have less common background from which assumptions arise (Emerson, 1983). In comparison to the learning objectives of Chapter 6’s taxonomy, this would aid in the effectiveness of the delivery, provide additional pathways for formal communication, and allow best practice between different groups to be compared and adopted. This interpretation was also supported by the results of the LFIQ, where ‘we discuss incidents, and what to do to prevent them, with our
Barriers to LFI

RQ3b: What barriers to learning exist in the LFI process?

- Workers were members of multiple activity systems, such as general safety and LFI. While the objectives of these systems were often compatible, that was not always the case.
- Incident alerts were often perceived as irrelevant. This was partially due to insufficient tools to correctly identify what incident alerts were relevant to different groups. However, cognitive biases also caused workers to perceive the incidents of others to be due to incompetence.
- Pedagogical practices of team supervisors engaging their team with incident alerts varied greatly. Tools created to distribute incident alerts were not built on pedagogical foundations.
- Incidents are dependent upon probabilities. As the tools to evaluate learning are limited to the number of incidents organisations are unable to differentiate between a workforce that is learning well and one that is fortunate.

The results of the LFIQ provided some initial insights into potential barriers to learning in the LFI systems of the three organisations. In each case the majority of the five lowest rated items asked about communication in the organisation. To more deeply analyse the underlying contradictions of the LFI systems discursive manifestations of contradictions were identified. As according to activity theory contradictions are unobservable (Engeström, 2000), individual sentences spoken by participants that hinted at a tension were coded with the elements that seemed to be in tension, such as the participant and the desires of another group (Saldaña, 2016). From these manifestations four underlying contradictions were deduced (Engeström & Sannino, 2011).

The first contradiction related to the fact that workers appeared to simultaneously belong to multiple activity systems, each with their own objectives. In particular, no differentiation was often made between the activity system for general safety and the activity system for learning from incidents. While safety and learning are often complementary in their aims and requirements, and ultimately general safety innovations and LFI both aim to reduce incidents, they differ in several significant ways (Littlejohn et al., 2014). Learning requires active reflection upon events, while safety is associated with the prevention of negative events (Biesta & Burbules, 2003; Hollnagel, 2014). In the thematic analysis conducted in Chapter 6 a safety mindset was mentioned as a learner characteristic by most participants. On the one hand, the safety mindset was described as an almost subconscious attitude of being cautious and being aware of your
surroundings. On the other hand, learning is an active process as reflective thought requires conscious effort (Dewey, 1910; M. Zhang & Quintana, 2012). The analysis in Chapter 6 showed that the meaning of learning in the context of LFI was diverse and many aspects remained tacit. As what successful learning entails was not explicit it was not obvious that there were some contradiction between the goals of safety and learning, hence tools such as incident alerts were made without this difference in mind. For example, 12 participants answered, when asked what someone learning well from incident alerts would do differently, that there should be no difference besides an increased awareness and caution. This response is consistent with incident alerts as a tool to develop a safety-oriented mindset. However, it is not sufficient for learning. This may additionally explain why several studies found that oversimplification of incidents was an issue, if alerts are just to remind workers to be careful then details are not required (Drupsteen & Hasle, 2014; Jacobsson et al., 2012; Lukic, 2012; Stemn et al., 2018).

This contradiction is closely related to the way that knowledge is conceptualised in activity theory (see Section 3.5). Workers interpret the objectives of the LFI process not only by considering the elements of the LFI system, but are additionally influenced by multiple other activity systems, such as production and general safety. In other words, behaviour is influenced not just by the elements of a single activity system, but by the wider cultural and historical moment an activity system exists within. The tools that are created to support LFI activities are likewise influenced by this broader context and can become unsuitable for achieving all of the objectives related to learning.

The second contradiction echoed a barrier that had been discovered in previous research: incident alerts are sometimes perceived as irrelevant (Drupsteen & Hasle, 2014; Lukic, 2012). There appeared to be two causes for this contradiction. The first, as determined by the results of the LFIQ and the SNA conducted in Chapter 5, was the top-down way incident alerts were disseminated. Decisions on what was relevant to which groups passed through multiple layers of subjective judgement by people who were removed from the actual daily tasks of the front-line workers. Without being an active participant in the work tasks it would be difficult for those distributing the incident alerts to know what was relevant to front-line participants (Billett, 2002). Second, there were no formal pathways to provide feedback to those selecting incident alerts on what was perceived as irrelevant by front-line workers. In other words, part of the reason that incident alerts were sometimes seen as irrelevant was because they were genuinely not related to the work of that group.

Nonetheless, the language used by participants highlighted a more subtle reason why incident alerts were viewed on occasion as irrelevant: there was a difference in the way that
workers thought about the reasons they were involved in incidents as opposed to those from other organisations. Incidents by unknown people were often described as being due to the incompetence of those involved, whereas incidents of those close to the participant were due to unavoidable situations. Catino and Patriotta (2013) in their study of pilots have previously provided an example of the second attitude, where incidents were understood as the result of a series of small misalignments in events. Other studies have shown that workers are inclined to place blame on the errors of individuals (Armitage et al., 2010). The analysis conducted in this thesis suggests that it is perhaps not that workers blame either an individual or attribute the cause to a complex chain of events, but are cognitively primed to attribute blame to those whose circumstances they do not understand (Tetlock, 1985). This has implications for learning, as if a worker thinks an incident could have been avoided by common sense they will not actively think on the information presented, assuming that they already know the best practice (Dunlosky et al., 2013).

The third contradiction regarded the lack of pedagogical consistency and consideration when presenting incident-information. In the qualitative SNA conducted in Chapter 5 participants outlined that their networks were important for discussion through which the incident-information was contextualised. However, productive dialogue often requires scaffolding (Häkkinen & Mäkitalo-Sieg, 2007; Murphy et al., 2019). In the SNA network-level analysis it appeared that team supervisors were the main entry point to a team for formal incident-information, and from the description of the activity system tools this primarily happened through either sending emails or presentations during team meetings. However, accounts of how team supervisors facilitated the introduction of the incident-information varied greatly. The tools of incident dissemination have also been created without pedagogical consideration, focusing on delivering incident-information to workers rather than providing scaffolding for them to engage with that information. LFI could learn from distance models of education which have created tools based on pedagogical foundations, such as adaptive systems (Littlejohn & Hood, 2018; Schumacher & Ifenthaler, 2018).

The final contradiction revolved around issues of identity that arose due to the probabilistic nature of incidents. Whether an incident occurs or not is dependent to an extent on the probability of a series of precautions all failing (Reason, 1995). Several participants expressed suffering an identity crisis following an incident, as they had felt their organisation was a world leader in safety, but an incident brought that belief into question. 19 participants felt that the only way to know whether learning was occurring or not was to look at whether the number of incidents was rising or not. However, three also commented that this was a difficult measure to understand as all three organisations in this thesis already had a low incident rate. Due to the
number of incidents occurring being the sole indicator of success it was impossible for workers to
disentangle whether that success was due to genuine competence and learning, or to good
fortune. If LFI is considered as an example of experiential learning (Leicher et al., 2013; Vastveit et
al., 2015), then this is problematic, as workers would never be able to reflect on events and
update their world views (Kolb, 1984). This contradiction speaks to the urgent need for more a
comprehensive evaluation of learning in LFI using some of the objectives outlined in Chapter 6’s
taxonomy. Not knowing if events are due to probability or incompetence means that there is the
potential for a shock to the identity of workers following an incident, which will then impact their
agency and engagement with LFI (Kira & Balkin, 2014; Lukic et al., 2013).

8.2.2 Methodological Contributions

Activity theory

- Used SNA in conjunction with activity theory
- Explored the use of versus coding to identify discursive manifestations of contradictions
- Explicit consideration of membership of multiple activity systems

While originating from different theoretical origins, SNA and activity theory present a
complementary view of the world (Murphy et al., 2020). The different emphases in the two
frameworks offer compatible perspectives on the social dynamics of workplaces, with SNA
centring on relationships, while activity theory examines the object-oriented activity of a
community (Engeström & Sannino, 2010; Wasserman & Faust, 1994). Furthermore, the
combination addresses some limitations of either approach when used independently: activity
theory places the results of SNA in a rich cultural context, while SNA provides in-depth
understanding and visualisations of tacit elements of a community.

However, a research design integrating these two approaches must be careful to not
violate any of the theoretical assumptions on which methods associated with these two
approaches are based. This thesis provides an example of a research design that has integrated
the two, and suggests five elements that should be considered when combined in a mixed
methods case study: sequence of data collection, importance of each method, boundaries, data
integration, and number and type of cases.

A further methodological innovation related to activity theory in this thesis is the use of
versus coding to identify discursive manifestations of contradictions. In their methodological
article, Engeström and Sannino (2011) criticised previous studies which had identified tensions in
dialogue in order to deduce contradictions, stating that tension was too generic a term. The use of versus coding allowed specific tensions to be identified and labelled, in a similar manner to the linguistics-based scheme suggested by Engeström and Sannino (2011). Versus coding had the added benefit of providing a more flexible tool that identified tensions that would have been missed in the linguistics-based analysis.

Finally, the contradiction analysis in Chapter 7 highlighted a potential limitation of activity theory. Activity theory is not very explicit in the fact that the same community with the same tools could be in multiple activity systems that have conflicting objectives, particularly as the objectives of each system are often only tacitly understood. The systems’ mediating elements, such as tools and rules, would therefore also develop contradictions due to trying to achieve contrary sets of objectives, likely leaving the mediating elements unable to support either set of goals. While this is novel in activity theory, the idea of a community possessing membership to multiple systems is explicit in SNA (Palonen et al., 2004).

This final innovation can be considered an extension Engeström’s (2000a) discussion around knowledge in activity theory. In his discussion of umpires in baseball Engeström points out that knowledge within an activity system is not only influenced by the elements of an activity system, but by the wider context. In Engeström’s example the umpire’s behaviour was determined by an immediate activity system related to baseball, and a second activity system related to gambling. The umpire was in effect a member of two activity systems, creating the possibility for contradictions to arise. While the third generation of activity theory is explicit in its consideration of multiple activity systems influencing each other, like two connected networks, it does not discuss the fact that a subject will always be a member of more than one activity system.

Subjects participating in multiple activity systems is novel as a form of contradiction in activity theory, but can be seen as an extension of well-established concepts in the activity theory literature.

**Thematic analysis**

- Data visualisation using heatmaps
- Intra-rater verification by splitting the data
- Validation using a workshop

While the steps followed here align closely with the well-established method described by Braun and Clarke (2006), there are three novelties worthy of discussion that can be considered as
contributions to the literature on thematic analysis. The first relates to data visualisation. In quantitative methods, guidelines on data visualisation are well-established; for example, graphs of distributions or sociograms. However, as qualitative methods are by their nature iterative, it is difficult to prescribe precise steps that should be followed every time leading to relatively little guidance on results visualisation (Saldaña, 2011). Thematic analysis is an approach that has gained popularity in recent years and has a relatively clear structure in its application (Bryman, 2016). For these reasons data visualisations that can accompany most thematic analyses as standard should be developed. While thematic analysis does not place heavy significance on the number of times topics are mentioned in the same way content analysis does (Hsieh & Shannon, 2005), the relative proportion of interview participants who mentioned certain themes helps add transparency and precision to reporting thematic analysis (Guest, MacQueen, & Namey, 2014). Visualisations in qualitative research are often creative, usually focusing on graphical depictions of relationships between themes and concepts (Kane & Trochim, 2007). A heatmap, such as the one used in this thesis to report the results of Chapter 6 (see Figure 29), departs from the usual visual representation of connections between themes. However, heatmaps are a valuable visualisation that provides a holistic view of frequency without necessarily attaching importance to the codes used most frequently. They allow a reader to instantly have an overview of which codes were mentioned frequently and set the scene for more detailed narrative.

The second innovation in the thematic analysis conducted in this chapter relates to constructing codes and themes using only a portion of the data before conducting discussion with peers. In this thesis, the interviews were not split on purpose when constructing the coding scheme, but rather due to practicalities when collecting the data. However, I found that applying the coding scheme to a new set of data was a great opportunity for reflection on the coding scheme. In qualitative research, opportunities for reflection are essential for increasing reliability and validity, for example through the involvement of multiple researchers (Twining et al., 2017) or returning to data multiple times and iteratively honing a coding scheme (Braun et al., 2019). Splitting the data, rather than using everything to create the coding scheme, was an additional opportunity for reflection and hence added to the validity of the eventual scheme (Nowell et al., 2017).

While I had not encountered this technique employed within the literature on qualitative research, there is a precedent within machine learning techniques that are used to analyse large amounts of both qualitative and quantitative data. In machine learning, data is initially split into a training set and a testing set. This splitting is done for the purpose of testing the predictive power of the algorithms derived from the training data. A thematic analysis is not done for the purpose of predicting the responses of participants, and thus differs substantially from machine learning.
approaches. However, as discussed by Flyvbjerg (2006), qualitative methods do hope to provide theoretically-generalizable results. If a set of codes and themes is sufficient to capture the complexity of data set that was not used to generate them, there is further evidence that the results could be useful beyond a single context. This guideline is particularly true when dealing with multiple case studies, as this thesis does. While I do not claim that the taxonomy derived here is universally true in all energy organisations, the fact that the taxonomy could be applied to Company B without any modifications lends support to its usefulness as a starting point for similar contexts to those discussed in this thesis.

The final contribution of the analysis approach used in this thesis also relates to the validity of the results by considering whether the results were credible in the eyes of participants (Nowell et al., 2017). As described by Yin (2013), construct validity relates to whether the results achieved are actually representative of the phenomenon studied. Presenting results back to participants is one way in order to assess construct validity. While I found making presentations to my participants and to wider representatives of the energy sector at conferences useful and provided some validation of the results based on discussion afterwards, I felt participants were inclined to accept what I said due to my position as an academic. Translating the findings of the thematic analysis into a workshop allowed participants to more actively engage with the taxonomy and truly consider whether it was relevant to their own environment. Collecting feedback at the end of the workshop also allowed me to gain data that supported my interpretation that participants found the taxonomy useful. Interestingly, upon reflection, I felt a close analogy to the topic of this thesis: when passively receiving information participants agreed with the conclusions and felt they were common sense, but through active engagement a more complex understanding and evaluation of the results were achieved.

8.3 Limitations

This thesis presented a mixed methods analysis of three separate energy organisations’ LFI systems. Multiple steps were taken to ensure the rigour, reliability, and validity of the research. Nevertheless, several limitations to the research contained within this thesis should be addressed in future research. One of the largest limitation is that despite using mixed methods, all measures were self-reported. In the future, researchers should collect observational data to assess how well employees’ reports match the observed reality. Although it can be difficult to obtain, data on the number of incidents would be valuable in assessing what practices are beneficial.

Another limitation related to the nature of the framework used within this thesis. Both SNA and activity theory focus on the group level of interaction but somewhat account somewhat
for individuals and workplace context, acknowledging their influence on group dynamics (Engeström & Kerosuo, 2007). Chapter 7 suggested that individual’s cognitive biases influenced how workers engaged with incident alerts (Tetlock, 1985). Alternative theoretical frameworks that consider both reflection and cognitive processes could therefore be a fruitful foundation to investigate this aspect of LFI. For example, probabilistic models of knowing take into account the cognitive aspect of learning, as they relate to the structure of information in the brain, but also acknowledge situational differences to account for perceptions in why different outcomes occur (Pearl, 2011; Tourmen, 2016).

Pedagogical practices arose as one of the areas that could potentially benefit the energy sector’s LFI systems. However, beyond accounts that the current way incident alerts are presented varies greatly, this thesis was unable to concretely advice on beneficial pedagogy. From the wider research on educational practices, recommendations for practitioners on what is likely to enable learning are made below. However, intervention studies that quantitatively assess the effects of different approaches would improve guidance for energy organisations on best practice. This research should include investigate meeting facilitation, in a similar but more pedagogically focused manner to (J. E. Anderson & Kodate, 2015; Nicolini et al., 2011b); and use of technology.

Finally, a large limitation of this research relates to the nature of case studies. While results were compared among three organisations, all three were situated within the energy sector. There are several high-risk industries that share similar imperatives to learn from incidents, such as healthcare and aviation, and replication of the research in this thesis in these contexts would be beneficial. As aviation is the industry reputed to possess the most effective LFI system (Le Coze, 2013; Syed, 2015), understanding the extent to which the barriers to learning highlighted in Chapter 7 are present within aviation could impact other sectors, stressing the immediate need for this research to be carried out.

8.4 Practical Implications
The results presented in this thesis contribute to knowledge through their theoretical and methodological innovations, as well as have implications that could be beneficial for practitioners. Networks are fundamental and important parts of all activities in the workplace. Chapter 5 demonstrated that networks play several functions in LFI. There are no prescribed “best” network structures that will work for organisations to support LFI, as the optimal situation will depend upon the circumstances of the organisation. However, there are three main considerations for organisations in their networks: how spatially distributed are workers, how many opportunities there are for workers to meet colleagues from outside their team, and how feedback is provided
to those distributing incident alerts. The more distributed workers are, the more technology will be needed to enable them to connect and locate information (e.g., email, WhatsApp). A well-structured digital system that recommends information, including incident-alerts, that are relevant to the tasks that will be undertaken that day is useful for any organisation, but especially for workers who would not be able to ask a nearby colleague for advice. In this situation, it is also important for official titles, such as coach or safety engineer, to exist so that workers know whom to contact if they cannot find the information themselves. Additionally, social media can allow distributed workers to discuss issues. While some platforms like Yammer have the functionality of a learning management system, they are unlikely to be used because checking them are not part of the daily routine of workers. Platforms such as WhatsApp or Facebook are therefore more likely to be successful.

According to the analysis of Chapter 5, front-line workers are primarily dependent upon their team supervisor for receiving formal incident-information. This dependency could be problematic if the team supervisor is not skilled at engaging the team with alerts. For this reason, team supervisors should be supported with facilitation skills training. Additionally, if representatives from each front-line team are invited to inter-departmental meetings, as happened in Company C, workers become less reliant on their team supervisor for information. There is also the added pedagogical benefit of discussion on incidents occurring between people with varied backgrounds.

Finally, from a network perspective, organisations must consider how feedback is provided to those distributing incident-information. This consideration is important to allow those distributing incident-information, such as the Health and Safety department, to assess if they are sending the correct information to the appropriate people. Furthermore, if one team decides to change their practice based on an incident-alert, this information could be shared with others through documented feedback. Incident databases could be modified to allow more dynamic discussions on what resulted from an incident-alert. Changes that surface in this manner would eventually need to be tied back to an official procedure. Even simple feedback could be useful when deciding which teams an incident-alert would be relevant to.

Chapter 6 provided an overview of different potential learning objectives. According to the analysis in Chapter 7, organisations are not currently differentiating between good safety and good learning. In addition, the incident rate was commonly mentioned as the only true indicator of both. Organisations could benefit greatly from thinking more concretely about what they want to achieve through the LFI process, which will then in turn lead to fewer incidents. Rather than focusing on outcomes, measures of some of the factors identified in Chapter 6 as necessary for
learning to occur could also be used to provide a more holistic understanding of whether learning is happening or not. Measuring all 24 learning objectives included in the taxonomy presented in this thesis is perhaps not feasible, but selecting a few key objectives of learning for an organisation and thinking about how to measure them would be a vast improvement on the current approach used by organisations.

The final recommendation for practitioners from this thesis is to think about the pedagogy supporting the LFI process. This not only includes well-facilitated team meetings, but specific events that will allow workers to focus on several incidents related to a process, rather than an incident in isolation. Other techniques could include small tests before presenting incidents so that they do not dismiss the incident alert as something they have seen before, or coming back to an incident alert to see if workers still remember the take-away message (Dunlosky et al., 2013).

8.5 Future Directions for Research

The results of this thesis highlight several avenues for future research that are vital for fully understanding how organisations can learn from incidents and prevent similar events. Chapter 5 demonstrated that networks play various roles within LFI and postulated that the team supervisors of front-line teams are key for bridging front-line workers to the incident-information entering the organisation through the networks of managers. Intervention studies exploring different types of events, such as trainings and meetings, that help team supervisors connect with the managerial team could provide valuable insights into this hypothesis.

Another area that should be explored in the future is whether the beneficial practices observed in the results of Chapter 7 could be of service to other industries. In healthcare, for example, some academics doubt that incident reporting can be of use to the sector (Macrae, 2015). However, many practitioners can understand the benefits of LFI (J. E. Anderson et al., 2013; T. Hewitt et al., 2016; Murphy, Lawrie, et al., submitted). If some of the beneficial practices identified in this thesis are implemented in healthcare they could provide evidence on whether LFI can be effective in that sector.

Finally, this thesis dealt with LFI in the context of a high-risk sector. Learning from the past is, nonetheless, not exclusive to high-risk industries. Creating a collection of cross-industry case studies to understand if and how different industries approach learning from undesirable events could illuminate valuable strategies regardless of context that allow organisations to develop and improve protocols.
8.6 Concluding Remarks

This thesis began with the story of my personal experience of the aftermath of the Fukushima disaster (2011). Throughout my PhD journey, I have made multiple mistakes along the way. It has only been through sharing with my supervisors, industrial colleagues, and fellow PhD students that I have been able to overcome obstacles and found ways around problems. While I have considered LFI as an organisational process of learning in this thesis, the truth is that reflection and open communication about events is vital for learning at every level: from individual PhD students to multinational energy companies, and everything in between.
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Appendix A: Social network survey

We are interested in how safety information and experiences are shared between people. We would like to know:

Who you would discuss problems related to safety within your team, e.g. how to safely move heavy equipment from one area of the site to another?

Who in the past 6 months you have received safety related information from, either through an official communication or at a meeting (e.g. an email announcement from your manager, from a colleague during a safety meeting, a safety alert)?

Please note that communication can take any form (e.g. talking, an email, a report), and could happen either inside or outside of work (e.g. at a social event).

The only people you need to check are your colleagues from whom you would ask advice or those who you have received safety related information from.

<table>
<thead>
<tr>
<th></th>
<th>In my team I would discuss safety problems with</th>
<th>In my team I have received safety information in an official communication or meeting during the past 6 months from</th>
</tr>
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<tbody>
<tr>
<td>Colleague name 1</td>
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<td>Colleague name 1</td>
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<tr>
<td>Etc.</td>
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</table>

In addition to members of your team, we are interested in knowing who else you would either discuss safety problems with, or receive safety information from through official notices or meetings. Please list these people in the following table. These people do not necessarily have to be part of your organisation. If you do not know who created the information then list where you found it.

<table>
<thead>
<tr>
<th>Person name or information location</th>
<th>Relationship</th>
<th>I would discuss safety problems with</th>
<th>I have received safety information in an official communication or meeting during the past 6 months from</th>
</tr>
</thead>
</table>
For the final question on this subject, please tell us about a recent time when you found safety information useful. How did you use this information to make your work safer? (Did you discuss it with a colleague and have a new idea? Did you take an idea from an accident at a different site and connect it to your work? etc.)
Appendix B: Interview Protocol

Expected research question: RQ2+RQ3

Expected activity system elements: Object/Tools

1. In the survey you described [information from survey]. Can you tell me more about that? / (If survey not completed ask ‘Can you tell me about a time when you’ve used information about an incident that you weren’t involved in?’) [PROBE: Where did you find the information?]

Expected research question: RQ2+RQ3

Expected activity system elements: Object/Tools

a. Did the information lead you to change your work in any way? [PROBE: In what ways did it change your work? Why did you change your work?]

Expected research question: RQ1

Expected activity system elements: Community/Division of labour

2. In your survey response you mentioned [answers] as people that you would discuss safety problems with. Why would you discuss safety issues with these people in particular? (If survey not completed first ask ‘Can you tell me who on your team you would discuss a safety problem with? How about outside of your team?)

Expected research question: RQ1+RQ3

Expected activity system elements: Community/Division of labour/Tools

3. In your answers you also mentioned [answers] as people that you have received information from through formal means. What kinds of information have you received from
them? (If survey not completed first ask ‘who do you receive safety information from through formal channels?)

[PROBE: How did you receive that information? What about it made it useful?]
c. How can [company] know if their workers are learning well from incident-information?
Appendix C: Ethical Approval

Human Research Ethics Committee (HREC)
From Dr Louise Westmarland
The Open University Human Research Ethics Committee
Email louise.westmarland@open.ac.uk
Extension (6) 52462
To Victoria Murphy
Project title Learning From Incidents and Implementing Action (LFIA)
HREC ref HREC/2017/2510/Murphy
AMS ref N/A

Date application submitted: 27/02/2017
Date of HREC response: 01/03/2017

This memorandum is to confirm that the research protocol the above-named research project, as submitted to the OU HREC for ethics review, has been given a favourable opinion by Chair’s action.

Please note the following:
1. You are responsible for notifying the HREC immediately of any information received by you, or of which you become aware which would cast doubt on, or alter, any information contained in the original application, or a later amendment which would raise questions about the safety and/or continued conduct of the research.

2. It is essential that any proposed amendments to the research are sent to the HREC for review, so they can be recorded and a favourable opinion given prior to any changes being implemented (except only in cases of emergency when the welfare of the participant or researcher is or may be affected).

3. Please include your HREC reference number in any documents or correspondence, also any publicity seeking participants or advertising your research, so it is clear that it has been reviewed by HREC and adheres to OU ethics review processes.

4. You are authorised to present this memorandum to outside bodies such as NHS Research Ethics Committees in support of any application for future research clearance. Also, where there is an external ethics review, a copy of the application and outcome should be sent to the HREC.

5. OU research ethics review procedures are fully compliant with the majority of grant awarding bodies and where they exist, their frameworks for research ethics.

6. At the conclusion of your project, by the date you have stated in your application, you are required to provide the Committee with a final report to reflect how the project has progressed, and importantly whether any ethical issues arose and how they were dealt with. A copy of the final report template can be found on the research ethics website - http://www.open.ac.uk/research/ethics/human-research/human-research-ethics-full-review-process-and-proforma#final_report

Best regards

Dr Louise Westmarland
The Open University Human Research Ethics Committee

www.open.ac.uk/research/ethics/ January 2017