UNIVERSITY OF WEST LONDON
The Career University

UWL REPOSITORY

repository.uwl.ac.uk

Learning From Incidents Questionnaire (LFIQ): the validation of an instrument designed to measure the quality of learning from incidents in organisations

Littlejohn, Allison, Margaryan, Anoush ORCID: https://orcid.org/0000-0002-1740-8104, Vojt, Gabriele and Lukic, Dane (2017) Learning From Incidents Questionnaire (LFIQ): the validation of an instrument designed to measure the quality of learning from incidents in organisations. Safety Science, 99. pp. 80-93. ISSN 0925-7535

http://dx.doi.org/10.1016/j.ssci.2017.02.005

This is the Accepted Version of the final output.

UWL repository link: https://repository.uwl.ac.uk/id/eprint/4820/

Alternative formats: If you require this document in an alternative format, please contact: open.research@uwl.ac.uk

Copyright: Creative Commons: Attribution-Noncommercial 4.0

Copyright and moral rights for the publications made accessible in the public portal are retained by the authors and/or other copyright owners and it is a condition of accessing publications that users recognise and abide by the legal requirements associated with these rights.

Take down policy: If you believe that this document breaches copyright, please contact us at open.research@uwl.ac.uk providing details, and we will remove access to the work immediately and investigate your claim.

This paper was accepted for publication in Safety Science on 10 February 2017

This post-print (final draft post-refereeing) is released under 'Creative Commons Attribution, Non-Commercial, No Derivatives License'

Learning from Incidents Questionnaire (LFIQ): The validation of an instrument designed to measure the quality of learning from incidents in organisations

Allison Littlejohn
Open University, Walton Hall, Milton Keynes MK7 6AA, UK
allison.littlejohn@open.ac.uk

Anoush Margaryan
Goethe University Frankfurt, Theodor-W.-Adorno-Platz 6, PF 14
60629 Frankfurt am Main, Germany
anoush.margaryan@gmail.com

Gabriele Vojt
Glasgow Caledonian University, Glasgow G4 0BA, UK

Dane Lukic
Glasgow Caledonian University, 70 Cowcaddens Rd, Glasgow G4 0BA, UK
dane.lukic@gcu.ac.uk

Abstract

Effective learning is essential for a safe workplace. Through learning from incidents (LFI), knowledge is applied and embedded within the work environment in ways that can prevent future incidents. In order to improve their LFI processes, such as incident reporting and analysis, or the dissemination of investigation outputs, organisations need an instrument that allows them to diagnose the quality and effectiveness of their LFI processes, making sure that LFI leads to positive safety outcomes. This paper outlines an instrument that measures the quality of LFI processes and practices: the Learning from Incident Questionnaire (LFIQ). The LFIQ identifies employees' perceptions and experiences of LFI processes and practices. This paper describes the validation of the LFIQ instrument via a pilot study conducted at two energy companies involving 781 participants. Through factor analysis the instrument was shown to have sufficient validity to become a useful tool for industry; by gaining insight into employees' perspectives on LFI, frontline managers and supervisors can have evidence on which to base improvements to the local work environment and prioritise areas for improvement.

1. Introduction

Effective learning from incidents (LFI) is critical for safe working. It allows knowledge to be applied and embedded in work environments in ways that can prevent future incidents (Cooke & Rohleder, 2006). However, learning processes often are not implemented effectively, since the design of LFI initiatives is seldom based on empirical evidence from research on Workplace and Organisational Learning (Lukic et al., 2010).

This paper was accepted for publication in Safety Science on 10 February 2017

This post-print (final draft post-refereeing) is released under 'Creative Commons Attribution, Non-Commercial, No Derivatives License'

In many organisations, the activities designed to enable employees to learn from incidents are based around the dissemination of the findings from incident investigations (see for example Phimister et al., 2003; Lundberg et al., 2009). However, dissemination of incident information does not always result in learning and action to change professional practice in the ways that are needed to prevent future incidents. In order to learn, people have to move beyond receiving incident information to actively engaging with this information and, where necessary, changing practice (Lukic et al., 2010). To do this, employees have to apply and make sense of incident information in ways that are meaningful to their job role; they have to reflect on the information and actively connect it to their professional practice (Lukic et al., 2013).

There are at least two main problems in moving individual employees towards actively engaging with incident information and, when necessary, changing practice (Lukic et al., 2013). First, many LFI activities focus on employees receiving and reading incident information, rather than engaging with incident knowledge. Second, during work there are few opportunities for employees to reflect and make sense of incident information in relation to their own job role. This problem is particularly acute with frontline employees. Front line managers and supervisors are not always able to engage front line employees with incident information in ways that maximise reflection and sense making. The research reported in this article is part of a larger study that aimed to address these problems. The need for a tool to measure LFI activity across each industrial site, and even across the sector, was heralded by the Energy Institute, a membership organization that wanted to measure employees' perceptions and experiences of learning from incidents within and across organizations. The study, Engaging with Learning From Incidents (LFI-Engage, http://www.gcu.ac.uk/academy/lflengage/), was funded by the Energy Institute to improve the effectiveness of LFI in organisations by supporting front line managers and supervisors in understanding the current status of LFI capability at their site, how this can be improved and how to more effectively engage with frontline employees on learning from incidents. The main output was a Toolkit designed to support front line managers and supervisors, especially with regards to encouraging sense-making and reflection within the LFI process. This paper reports the development and validation of a tool from the Toolkit, the LFI Questionnaire tool, which is designed to diagnose the quality of current LFI activities in an organisation with a view to understanding how these activities might impact on each individual's learning.

Research by Lähteenmäki et al. (2001) was the first to suggest that the initial step in improving LFI should be to examine existing LFI activities within each organisation. Arguably, this process calls for a valid and reliable instrument, which is sensitive to specific features of organisational learning (Easterby-Smith, 1998; Gherardi & Nicolini, 2000). There are a number of methodological approaches that could be used to diagnose quality of LFI, including ethnographic (Buescher et al., 2009), 'sensemaking' (Snowden, 2002), socio-cultural (Sanne, 2008) and cognitive-psychology based approaches (Stanton & Walker, 2011). The associated instruments are difficult for managers and supervisors to implement for various reasons – primarily because they are too specialised and technical to be used by non-researchers and are therefore out of scope for use by frontline staff.

LFI must be considered across the whole organization, or site, to capture all facets of the LFI process across different levels (Lukic et al., 2012a). The primary reason is because the cumulative effects of individual LFI activities across a site impact on the overall success - or failure - of LFI within an organisation. However, no instrument to measure LFI across an organization is currently available. This paper proposes an instrument, the Learning from Incident Questionnaire (LFIQ), to measure the quality of LFI processes and practice across an organization or site.

This paper was accepted for publication in Safety Science on 10 February 2017

This post-print (final draft post-refereeing) is released under 'Creative Commons Attribution, Non-Commercial, No Derivatives License'

2. Conceptual underpinnings

A comprehensive review of the literature was conducted to investigate existing models to provide a theoretical and conceptual platform for the questionnaire. Chiva et al. (2006) summarise that diagnostic instruments measuring the effectiveness of organisational learning tend to focus on two conceptual areas: (1) learning activities and their sequence, and (2) specific factors facilitating effective learning. With regards to the former, instruments addressing learning activities and their sequencing typically measure discreet phases of the learning process, for example the work of Drupsteen, Groeneweg, and Zwetsloot (2013) who conceptualised LFI as a series of steps to understand loss of learning potential in the process. In contrast, facilitating learning is based on measuring well-established properties or components (i.e. factors) which aid in effective learning. These two features - the activities and the factors inherent to effective learning - are interrelated as the *what* and *how* of learning. That is, the activities required to achieve effective learning outcomes are triggered by the factors associated with effective learning. Both these notions have been incorporated into instruments designed to measure safety climates, such as the Nordic Safety Climate Questionnaire, where learning activities (the *what*) are a subscale of safety climate (Kines et al., 2011); specific factors that enable learning (the *how*) have also been considered subscales of safety climate instruments, for example, individual motivation (Nielsen, Hystad, & Eid, 2016) and commitment to the workplace (Nielsen, Rasmussen, Glasscock, & Spangenberg, 2008).There are also tools aimed specifically at measuring the quality of organisational learning that cover both conceptual features, such as the instrument for Organisational Climate for Learning from Errors at Work (OLE) (Putz et al., 2013) or the model proposed by Edmondson (1999) relating team psychological safety, learning behaviours and performance. However, these tools tend to focus on a single organisational factor (e.g., learning climate) rather than the quality of the overall LFI processes. The conceptual baseline for the LFIQ were two models, developed through earlier empirical research: the LFI Framework (Lukic et al., 2012a) and the LFI Process Model (Lukic et al., 2012b). The reason these models were selected is because they were the first within the literature in this field to explore learning activities across the various phases of LFI (Lukic et al., 2010).

2.1. The LFI Process Model

The LFI Process Model (Figure 1) is used to map LFI activities across a site to phases of the LFI lifecycle (Lukic et al., 2012b). The LFI Process Model was developed through analysis of LFI activity on different industrial sites. There are normally six phases of LFI: reporting incidents, investigating incidents, developing incident alerts, disseminating information, contextualising information and implementing actions.

This paper was accepted for publication in Safety Science on 10 February 2017

This post-print (final draft post-refereeing) is released under 'Creative Commons Attribution, Non-Commercial, No Derivatives License'

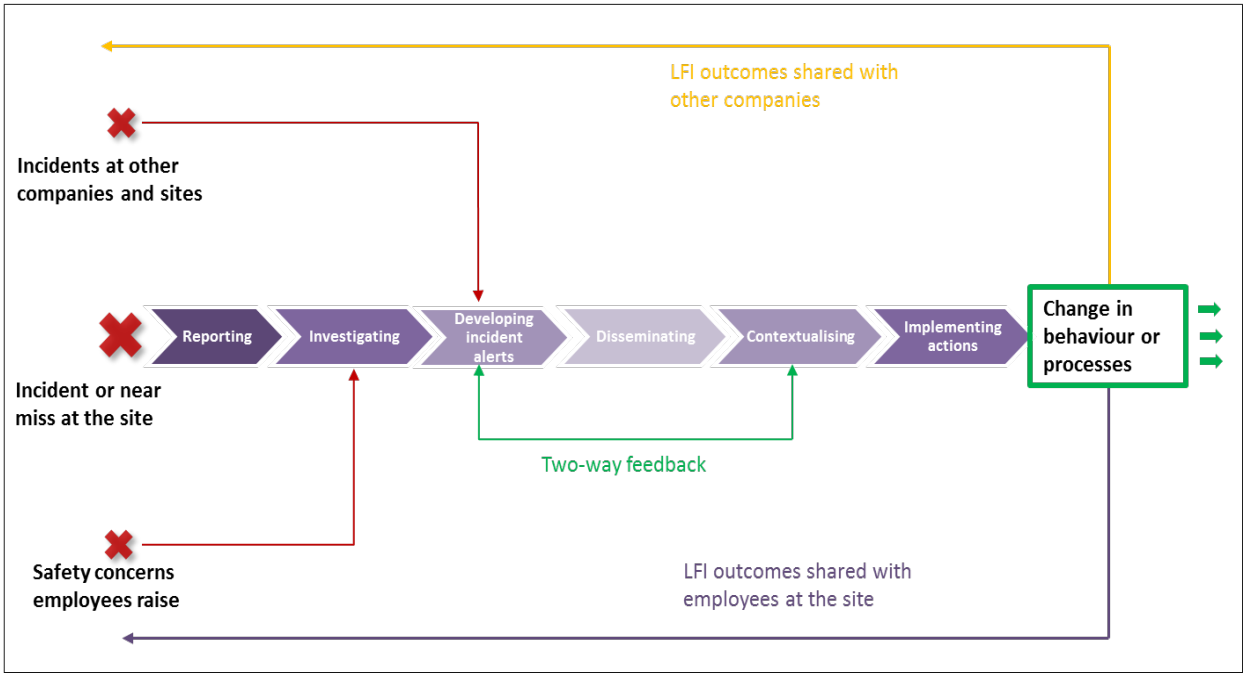

Figure 1. The LFI Process model

The LFI Process Model describes these phases as sequential. That is, (1) reporting an incident (including a near miss) is essential in raising awareness and allowing for preventive actions to be formulated. This leads to an (2) investigation of the incident(s) to determine both the immediate and underlying causes of the incident. Based on this investigation, recommendations for improving safety or changing practice are developed and shared across the relevant site in the form of an (3) incident alert. Incident alerts are tools to help employees understand how to prevent similar incidents from reoccurring. (4) Dissemination should be targeted towards relevant rather than all groups of workers, i.e., those employees who will benefit from each particular incident alert. The (5) contextualisation phase is important in learning as incident information has to be critically assessed and reflected upon within each employee's relevant workplace context. The final phase requires the (6) implementation of actions and changes by all relevant employees, thereby using the information with the aim of preventing similar incidents in the future.

This process forms a foundation to understand the effectiveness and inter-relationship of existing LFI activities on sites.

2.2. The LFI Framework

Before 2012, Learning from Incidents was not underpinned by theories of organisational or adult learning (Lukic et al., 2012a). The LFI Framework (Figure 1) represents an early attempt to underpin LFI activity with these theories (*ibid*), taking into consideration critical components that influence organizational learning, such as how lessons are learned, the severity of the consequences of an incident and the people involved as well as team learning components, such as trust (Edmondson,1999). The Framework was selected as a baseline for the LFIQ because it integrates concepts from diverse yet related learning theories that: a) serve as analytical lenses to understand facets of LFI and b) provide prescriptive values when developing interventions in LFI. The

This post-print (final draft post-refereeing) is released under 'Creative Commons Attribution, Non-Commercial, No Derivatives License'

framework is based on five key learning components identified through the literature as being important for effective LFI (for a detailed description of each component see Lukic et al., 2012a):

1. Learning context – learning might be organised and structured (e.g., courses or training) or could be informal (e.g., on-the-job learning). Informal learning is more difficult to perceive as 'learning' per se;
2. Learning participants – people in diverse roles or different areas of the organisation may prefer distinctive ways of learning;
3. Learning process – there are different reasons for learning that may require different processes. The learning process has to align with specific learning goals;
4. Type of incident – a large-scale and complex incident will require a different learning solution compared to a small-scale incident;
5. Type of knowledge – different sorts of activities are required to learn different types of knowledge. For example, theoretical and practical knowledge are learned in different ways.

Figure 2. The LFI Framework (Lukic et al., 2012a)

These two perspectives, the temporal and sequential learning phases of the LFI Process Model and the underpinning learning components of the LFI Framework, function together in an effective LFI process.

This paper was accepted for publication in Safety Science on 10 February 2017

This post-print (final draft post-refereeing) is released under 'Creative Commons Attribution, Non-Commercial, No Derivatives License'

3. Design of LFIQ

In line with the LFI Process Model and Framework used to inform the LFIQ, we developed two sets of related scales: the learning component scale (e.g., formality of learning) and the learning phase scale (e.g., reporting). Each learning component was broken down into specific dimensions, which were then coded with the relevant learning phases. The link between learning component dimensions and the related learning phases was achieved through formulating a latent question that would lead to the development of a specific statement. In other words, each phase of the LFI process contained multiple statements that would be rated to assess a learning component crucial during that phase. Appendix A details the operationalization of each of the five learning components, illustrating the latent questions and relevant learning phases from the LFI Process Model. For each learning component three or four latent questions were created, designed to capture the essence of a dimension of that particular learning component. For each latent question one to three learning phases was identified. A statement item was then developed for each of phase identified in a dimension of a component. Each statement was therefore associated with both a learning component and a learning phase.

The questionnaire consisted of two parts. Part 1 related to the background of respondents (9 questions) while part 2 the statements outlined above which respondents rated using a 5 point Likert scale ranging from 1 = strongly disagree to 5 = strongly agree. Each question focuses on one learning component within a single phase of LFI.

There were five learning component scales:

1. Type of problem (6 items)
2. Learning participants (11 items)
3. Learning processes (8 items)
4. Type of knowledge (4 items), and
5. Formality of learning (5 items).

Matching these, six learning phase scales were developed:

1. Reporting (5 items)
2. Investigating (3 items)
3. Developing incident alerts (9 items)
4. Disseminating (8 items)
5. Contextualising (14 items), and
6. Implementing actions (6 items).

The 'developing incident alert' items were sensitive to respondents in that only those who indicated in Part 1 that they were involved in this particular process were asked to complete these items. This meant that the total questionnaire items ranged between 36 and 45 items depending on the respondent's designation. Table 1 outlines a number of item examples demonstrating how these map onto the learning component and the learning phase scales.

This paper was accepted for publication in Safety Science on 10 February 2017

This post-print (final draft post-refereeing) is released under 'Creative Commons Attribution, Non-Commercial, No Derivatives License'

Table 1. Examples of questionnaire items

Item	Learning component scale	Learning phase scale
Q23. Our company has a system in place that allows all employees to easily report incidents.	Participants of learning	Reporting
Q35. We consider if the incident information we receive is relevant to our own work.	Type of problem	Contextualising
Q44. The incident information we receive helps us understand which procedures we need to follow in order to prevent future incidents.	Type of knowledge	Contextualising

4. Validation of LFIQ

We tested the validity and applicability of the LFIQ across two sites in two different, multinational, energy companies. Site 1 was a large upgrader site within a multinational company in the oil and gas sector in Canada, with around 1500 employees. Site 2 was a wind power plant within a UK energy company, with around 60 employees. We chose to include both sites in the utility testing to increase the applicability of the instrument to different companies. This noted, caution is advised as applicability does not necessarily infer generalisability. For example, the total sample size is limited, and therefore cannot be considered representative of diverse companies and sites.

4.1. Content Validity

Content validity was established through two mechanisms: expert interviews and a pilot study.

4.1.1. Expert interviews

To ensure that the instrument effectively captured the topic under investigation we interviewed 'experts', in other words, those who have an in-depth understanding of the topic of the instrument (LFI) through focus groups. The experts were front line managers, safety managers and contractor representatives. When designing the questionnaire, we used principles of questionnaire design (Peterson, 2000; Oppenheim, 1996; Olsen, 2012). We also utilised feedback from six practitioners to sharpen the items prior to conducting the expert interviews in the form of focus groups. These focus groups were conducted on each of the two industrial sites. Sampling was facilitated by nominated gatekeepers who recruited a cross-section representing a stratified convenience sample. The Site 1 focus group comprised of 14 participants while the Site 2 focus group consisted of 7 interviewees. The focus groups were recorded, transcribed and coded using NVIVO. Thematic analysis was carried out on the focus groups transcripts. The reason thematic analysis was selected as a methodology, rather than open coding, was because the themes had already been established through the earlier literature review (Lukic et al, 2012). Thematic analysis was used to gather feedback from experts to understand if the items of the questionnaire reflected important themes within each category. This procedure was suggested by Nassar-McMillan and Borders (2002, p. 6) who noted

This paper was accepted for publication in Safety Science on 10 February 2017

This post-print (final draft post-refereeing) is released under 'Creative Commons Attribution, Non-Commercial, No Derivatives License'

that although there are no clearly defined rules for the use of focus groups in measurement development, they aid in comparing groups' reactions to the same concepts and providing richer data for developing valid instruments. The coding was performed by one researcher and cross-coded independently by two further researchers. The coding was cross-checked and refined where inconsistencies arose to improve the overall reliability.

The emergent themes used for the analysis were defined by the earlier research on LFI phases and learning components. Qualitative analysis was used to determine whether sufficient content related validity evidence existed. Test content refers to the themes, wording, and format of the items, tasks, or questions on a test. Content validity was critical and the thematic analysis explored whether the items held the same meaning for people within and between groups and whether the items adequately operationalized the concepts they were developed to assess. If items were not found to adequately operationalize a concept, then an attempt was made to determine whether this was due to unclear wording or insufficient shared conceptual understanding.

We used thematic analysis to examine emergent themes within and between sites. Interviewees were asked to explain each LFIQ question in their own words. We also presented the outcomes of each question using the data gathered from their site and invited their views on the accuracy of the outcomes.

Where appropriate, we revised items according to participants' feedback. For example, interviewees provided alternative wording suggestions for a number of items thought to be unclear. A detailed account of the methodology and results of the focus groups have been published elsewhere (Lukic et al., 2013). However, the validation of the LFIQ Tool within single-site testbeds in two organisations has not been published and is the focus of this paper. The pilot study is described below to provide a baseline for the instrument validation.

4.1.2. Pilot study

We conducted a pilot study in order to test the clarity of the LFIQ questions. The aim of the pilot study was to assess how well the wording of the LFIQ questions would be understood by the target user groups. We purposefully selected nine practitioners who worked in one of the two energy companies involved in the study. To enhance the representativeness of the sample we included people from various roles at different levels across the organisational hierarchy. We aimed for a cross-section of practitioners, i.e. we chose individuals from diverse professional backgrounds, in order to provide diverse points of views and enhance representativeness across the organisation. All nine respondents received an online version of the LFIQ and were asked to comment on the clarity and structure of questions. Six practitioners completed the questionnaires, and two of these also agreed to a follow-up interview regarding the clarity of the questions. Based on the feedback, selected questions were modified to improve the clarity of the questionnaire in the initial phases of the instrument development.

4.2. Construct Validity

To determine construct validity, we distributed the LFIQ across both sites through site-wide bulletins sent via email. The bulletins invited employees to participate in the study, and provided a summary

This paper was accepted for publication in Safety Science on 10 February 2017

This post-print (final draft post-refereeing) is released under 'Creative Commons Attribution, Non-Commercial, No Derivatives License'

of the study and a rationale for the LFIQ. We informed all potential respondents that participation was voluntary. The total number of responses from Site 1 was 740 (response rate of 50%) and 41 from Site 2 (response rate of 67%). Table 2 indicates the number of respondents by role. While questionnaires dealing with perceptions can be susceptible to social desirability, i.e., respondents answering in ways they view as desirable rather than accurate, the effects of this were minimised in two ways: question design (questions related to organisational states rather than individual qualities), and by conducting the study as self-administered and anonymous (Nederhof, 1985).

Table 2: Number of respondents by role

Type of role	**Site 1**		**Site 2**	
	%	N	%	N
Senior manager	1.2	9	7.3	3
Middle manager	4.5	33	14.6	6
Immediate supervisor of front-line/shop-floor workers	14.5	107	26.8	11
Front-line/Shop-floor worker	68.9	510	46.3	19
Health, Safety, Security, Environment (HSSE) Professional	8.0	59	0	0
Administration	1.1	8	4.9	2
Missing values	1.9	14	0	0
Total		*740*		*41*

Factor analysis

A factor analysis was carried out to explore the underlying structure and statistical components of the LFIQ. An exploratory factor analysis is recommended when the underlying structure of the dataset is not known, and when there are no preconceived hypotheses regarding the number and nature of factors. A principle component analysis, in contrast, is of a more confirmatory nature. That is, this method seeks to confirm if the number of factors identified conform to the researchers' expectations based on previous results. An initial assessment of the data was carried out to determine the suitability of the data for factor analysis, i.e. whether the assumptions required for factor analysis have been met, and to determine sampling adequacy.

Suitability and Sampling adequacy of data

We initially assessed the suitability and sampling adequacy of the data via three methods: item-to-respondent ratio, Kaiser-Meyer-Olkin measure of sampling adequacy and Bartlett's test of sphericity. The number of respondents from Site 1 (N=740) was above the suggested 1:10 item-to-respondent ratio, making the scales suitable for factor analysis. The Kaiser-Meyer-Olkin measure of sampling adequacy of the Validation data ranged from .70 to .90 for all scales, which is above the minimum recommended value of .60. The Bartlett's test of sphericity for all scales was significant with $p<.001$, meeting the minimum requirement of $p < .05$. These tests indicated that the data at Site 1 were suitable for principal component analysis. Due to the small size of the sample from Site 2 (N=41) factor analysis was not performed on the Site 2 dataset. Although the response rate from site 2 was relatively high (67%), the number of responses is not sufficient to ensure that factor analysis results are meaningful.

This paper was accepted for publication in Safety Science on 10 February 2017

This post-print (final draft post-refereeing) is released under 'Creative Commons Attribution, Non-Commercial, No Derivatives License'

Principle Component Analysis

Principal component analysis (PCA) was used both on a global and on a local scale for Site 1. The global analysis reveals the importance of one prominent factor that could measure the global quality of LFI at the site. The relatively low number of observations with respect to the number of variables may produce inaccuracies in the estimation of the global correlation structure, though locally, factor analysis was also used on each scale separately, as they offered clear factor structure. We used varimax rotation despite the majority of scales being mono-factorial. This is in line with Gorsuch (1983) who recommends to use varimax rotation (for orthogonal rotation) if the 'simple structure is clear' in the data (p.205). In cases where the analysis resulted in factors with less than 3 variables loading more than 0.5, PCA was repeated limiting the number of factors (Barbaranelli, 2006).

Global PCA

A global PCA was used to identify which of the LFI variables correlate into single components. This test was carried out using the available data on the 'Developing incident alerts' scale. We ran the analysis on the complete questionnaire (125 questions) and, respectively, on the sub-questionnaire obtained after the removal of the Developing incident alerts scale (653 complete questionnaires with 36 questions).

Shapiro-Wilk normality tests on each question indicated non-normality in the distribution of observations. This is confirmed by a negative skew in each answer and the fact that answer "4" exceeds 50% in 26 out of the 45 questions. The conclusion of both diagonalisations are similar: one direction summarises a major proportion of the variance (35.59% and 35.21%, respectively for each diagonal). The remainder of the eigendirections accounts separately for very little (a maximum of 6.5%, decreasing rapidly). The loadings for the one-factor factor analysis (in the first analysis) are illustrated below in Table 3.

Table 3: Loadings for the one-factor factor analysis

LFIQ question		**One Factor Loading**
Q56	Our company listens to employees' ideas and suggestions for improving safety.	0.785
Q54	Employees are informed about the outcomes of implementation of incident prevention recommendations/actions.	0.767
Q39	The employees at this site can offer their recommendations for preventing future incidents.	0.749
Q52	At our work-site, we learn from near misses and incidents.	0.740
Q46	The incident information we receive helps us understand which procedures we need to follow in order to prevent future incidents.	0.734
Q45	We receive information about incidents that allows us to understand what really happened and how we can learn from it.	0.709
Q48	Incident information we receive suggests useful safety attitudes and values that can help us prevent future incidents.	0.707
Q51	We make a clear plan of action at the end of safety meetings.	0.695
Q50	At this work-site, we consider if we need to change the way we conduct work	0.678

This paper was accepted for publication in Safety Science on 10 February 2017

This post-print (final draft post-refereeing) is released under 'Creative Commons Attribution, Non-Commercial, No Derivatives License'

	based on the incident information we receive.	
Q23	Incident investigations are conducted in such a way that allows employees to be honest.	0.677
Q24	We identify all the root causes of an incident before implementing further improvements.	0.673
Q53	We discuss whether safety recommendations from previous incidents are appropriate for our work before implementing them at our work-site.	0.671
Q44	We always receive responses to feedback we give on incident information.	0.670
Q31	Employees at this site make sure that important information about incidents is shared with other employees who might benefit from it.	0.670
Q38	At our work-site, we receive all the relevant incident information discussed at safety meetings.	0.668
Q33	At this work-site, we discuss incidents and what to do to prevent them with our colleagues outside safety meetings and safety-specific communications.	0.668
Q40	At our work-site, we often give feedback to the authors of incident information.	0.663
Q49	There is a system in place for informal contribution of ideas and suggestions regarding safety and past incidents.	0.655
Q15	When preparing incident information/lessons learned, we tell employees where to find more information about the incident.	0.640
Q32	Information about incidents reaches all employees, even if they were away (off shift or on leave) when the incident information was disseminated.	0.639
Q28	Employees are routinely informed about the progress and outcomes of incident investigations.	0.637
Q22	Our company has a system in place that allows all employees to easily report incidents.	0.634
Q42	We recognise when a piece of information about safety from our private discussions is important for the rest of the organisation.	0.632
Q43	We inform the safety department about good ideas related to safety that arise from our informal discussions.	0.620
Q25	Incident investigations are conducted by a professional team who understand the nature of incidents.	0.620
Q18	At our site we report both incidents and near misses.	0.606
Q47	We know where to find relevant information regarding incidents so that we can prevent future similar incidents.	0.602
Q36	We actively discuss incident information with our colleagues.	0.599
Q16	When we disseminate incident information/lessons learned, we outline the attitudes and values that could help prevent another incident.	0.585
Q27	At our work-site, we receive incident information that is relevant to our work.	0.583
Q29	Employees who do not regularly use computers at our work-site receive the same information about incidents as other employees.	0.582
Q41	We can comment on incident information we receive if we disagree with it.	0.577
Q20	The management at our site consistently encourages reporting of incidents.	0.560
Q13	When preparing incident information/lessons learned, we clearly point out why an incident has occurred.	0.547
Q17	We can report incidents without fear of repercussions.	0.520
Q14	When developing incident information/lessons learned, we clearly point out which procedures need to be followed to avoid future incidents.	0.490

This paper was accepted for publication in Safety Science on 10 February 2017

This post-print (final draft post-refereeing) is released under 'Creative Commons Attribution, Non-Commercial, No Derivatives License'

Q26	At our work-site, we modify the way we learn from incidents depending on the nature of the incident.	0.472
Q11	Clear recommendations and actions are suggested in the incident information/lessons learned we disseminate across the site after an incident.	0.471
Q30	All employees eventually get to hear about incident information that other colleagues discussed informally.	0.438
Q37	We continually question incident information we receive.	0.438
Q9	When developing incident information/lessons learned, we adapt the content to suit different employees who will be receiving them.	0.415
Q35	We consider if the incident information we receive is relevant to our own work.	0.414
Q10	We apply different learning approaches when learning form complex incidents compared with the approaches we use for simple incidents.	0.375
Q12	When preparing incident information/lessons learned, we decide whether the incident is relevant to the whole site or to specific work groups.	0.343
Q21	Incidents at our site do not get reported due to fear of negative consequences.	0.332
Q19	At our workplace incidents are sometimes reported informally to colleagues without a formal record of the report.	0.217
Q55	We follow the recommendations/actions in incident information without discussing them first.	0.185
Q34	We hear about incidents through informal discussions with our colleagues rather than through formal safety information systems.	0.152

There is a slight increase in the loadings for the latter questions, which indicates that this direction intuitively measures the global quality of LFI at the site and the last phase plays a prominent role in the questionnaire. However, no single component plays a specific role in determining the global quality of the Learning from Incidents Questionnaire.

Local PCA

1. Learning Phase scales

A local factor analysis was conducted using only the data from Site 1. Four learning phase scales were identified as mono-factorial (Reporting, Investigation and Disseminating and Implementing actions) and two as bi-factorial (Developing incident alerts and Dissemination). Table 4 describes the factor loadings for the four mono-factorial scales and illustrates how each item performs within each scale/component. The factor loadings for three questions (Q19, Q34 and Q55) were below the acceptable level of 0.5. The PCA results for the mono-factorial LFI scales indicated that the learning phase scales can be viewed as bounded constructs.

This paper was accepted for publication in Safety Science on 10 February 2017

This post-print (final draft post-refereeing) is released under 'Creative Commons Attribution, Non-Commercial, No Derivatives License'

Table 4. Factor analysis of the mono-factorial learning phase scales

Scale	Items		Factor loading
	Q17	At our workplace incidents are sometimes reported informally to colleagues without a formal record of the report.	0.77
	Q18	At our site, we report both incidents and near misses.	0.77
	Q21	Incidents at our site do not get reported due to fear of negative consequences.	0.71
	Q22	Our company has a system in place that allows all employees to easily report incidents.	0.65
	Q20	The management at our site consistently encourages reporting of incidents.	0.63
	Q19	At our workplace incidents are sometimes reported informally to colleagues without a formal record of the report.	0.37*
Investigating	Q24	We identify all the root causes of an incident before implementing further improvements.	0.85
	Q23	Incident investigations are conducted in such a way that allows employees to be honest.	0.84
	Q25	Incident investigations are conducted by a professional team who understand the nature of incidents.	0.84
Disseminating	Q31	Employees at this site make sure that important information about incidents is shared with other employees who might benefit from it.	0.80
	Q28	Employees are routinely informed about the progress and outcomes of incident investigations.	0.78
	Q32	Information about incidents reaches all employees, even if they were away (off shift or on leave) when the incident information was disseminated.	0.78
	Q27	At our work-site, we receive incident information that is relevant to our work.	0.71
	Q29	Employees who do not regularly use computers at our work-site receive the same information about incidents as other employees.	0.71
	Q33	At this work-site, we discuss incidents and what to do to prevent them with our colleagues outside safety meetings and safety-specific communications.	0.68
	Q30	All employees eventually get to hear about incident information that other colleagues discussed informally.	0.64
	Q26	At our work-site, we modify the way we learn from incidents depending on the nature of the incident.	0.56
	Q34	We hear about incidents through informal discussions with our colleagues rather than through formal safety information systems.	0.38*
Implementing	Q51	We make a clear plan of action at the end of safety	0.81

This post-print (final draft post-refereeing) is released under 'Creative Commons Attribution, Non-Commercial, No Derivatives License'

actions		meetings.	
	Q53	We discuss whether safety recommendations from previous incidents are appropriate for our work before implementing them at our work-site.	0.80
	Q54	Employees are informed about the outcomes of implementation of incident prevention recommendations/actions.	0.79
	Q52	At our work-site, we learn from near misses and incidents.	0.78
	Q56	Our company listens to employees' ideas and suggestions for improving safety.	0.74
	Q55	We follow the recommendations/actions in incident information without discussing them first.	-0.19*

The bi-factorial learning phase scales are outlined below. The results of the analysis for the Developing incident alerts and the contextualising scales are illustrated in Table 5.

Table 5. Factor analysis of the Developing incident alerts and contextualising scale

Scale	**Items**		**Factor loading**	
			1	**2**
Developing Incident Alerts Scale	Q13	When preparing incident information/lessons learned, we clearly point out why an incident has occurred.	0.79	
	Q16	When we disseminate incident information/lessons learned, we outline the attitudes and values that could help prevent another incident.	0.75	
	Q14	When developing incident information/lessons learned, we clearly point out which procedures need to be followed to avoid future incidents.	0.73	
	Q11	Clear recommendations and actions are suggested in the incident information/lessons learned we disseminate across the site after an incident.	0.67	
	Q15	When preparing incident information/lessons learned, we tell employees where to find more information about the incident.	0.66	
	Q10	We apply different learning approaches when learning form complex incidents compared with the approaches we use for simple incidents.		0.86
	Q9	When developing incident information/lessons learned, we adapt the content to suit different employees who will be receiving them.		0.84
	Q12	When preparing incident information/lessons learned, we decide whether the incident is relevant to the whole site or to specific work groups.		0.72
Contextualising scale	Q45	We receive information about incidents that allows us to understand what really happened and how we can learn from it.	0.75	

This paper was accepted for publication in Safety Science on 10 February 2017

This post-print (final draft post-refereeing) is released under 'Creative Commons Attribution, Non-Commercial, No Derivatives License'

	Q44	We always receive responses to feedback we give on incident information.	0.75	
	Q49	There is a system in place for informal contribution of ideas and suggestions regarding safety and past incidents.	0.75	
	Q47	We know where to find relevant information regarding incidents so that we can prevent future similar incidents.	0.73	
	Q48	Incident information we receive suggests useful safety attitudes and values that can help us prevent future incidents.	0.68	
	Q38	At our work-site, we receive all the relevant incident information discussed at safety meetings.	0.67	
	Q43	We inform the safety department about good ideas related to safety that arise from our informal discussions.	0.62	
	Q40	At our work-site, we often give feedback to the authors of incident information.	0.62	
	Q39	The employees at this site can offer their recommendations for preventing future incidents.	0.61	
	Q41	We can comment on incident information we receive if we disagree with it.	0.60	
	Q50	At this work-site, we consider if we need to change the way we conduct work based on the incident information we receive.	0.58	
	Q46*	The incident information we receive helps us understand which procedures we need to follow in order to prevent future incidents.	0.47*	0.17*
	Q37	We continually question incident information we receive.		0.71
	Q36	We actively discuss incident information with our colleagues.		0.69
	Q35	We consider if the incident information we receive is relevant to our own work.		0.66
	Q42	We recognise when a piece of information about safety from our private discussions is important for the rest of the organisation.		0.52

Results for the Developing incident alerts scale demonstrate that all variables load significantly onto the two sub-factors and provide good validity of the construct. All but one item had factor loadings above the standard; Q46 had loading just under the required 0.5 and was noted for further analysis.

Learning Component Scales

A second factor analysis was carried out using the learning component scales. Results indicate that four scales were mono-factorial (Type of problem, Learning participants, Type of knowledge and Formality of learning) and one was bi-factorial (Learning process). Table 6 illustrates the factor loadings for the mono-factorial learning component.

This paper was accepted for publication in Safety Science on 10 February 2017

This post-print (final draft post-refereeing) is released under 'Creative Commons Attribution, Non-Commercial, No Derivatives License'

Table 6. Factor analysis for the mono-factorial learning component scales

Scale	Items		Factor loading
Type of problem	Q51	We make a clear plan of action at the end of safety meetings.	0.76
	Q53	We discuss whether safety recommendations from previous incidents are appropriate for our work before implementing them at our work-site.	0.74
	Q25	Incident investigations are conducted by a professional team who understand the nature of incidents.	0.66
	Q26	At our work-site, we modify the way we learn from incidents depending on the nature of the incident.	0.65
	Q36	We actively discuss incident information with our colleagues.	0.63
	Q35	We consider if the incident information we receive is relevant to our own work.	0.52
	Q55	We follow the recommendations/actions in incident information without discussing them first.	-0.21*
Participants of learning	Q28	Employees are routinely informed about the progress and outcomes of incident investigations.	0.75
	Q44	We always receive responses to feedback we give on incident information.	0.73
	Q39	The employees at this site can offer their recommendations for preventing future incidents.	0.71
	Q38	At our work-site, we receive all the relevant incident information discussed at safety meetings.	0.71
	Q32	Information about incidents reaches all employees, even if they were away (off shift or on leave) when the incident information was disseminated.	0.71
	Q56	Our company listens to employees' ideas and suggestions for improving safety.	0.70
	Q29	Employees who do not regularly use computers at our work-site receive the same information about incidents as other employees.	0.70
	Q40	At our work-site, we often give feedback to the authors of incident information.	0.70
	Q41	We can comment on incident information we receive if we disagree with it.	0.67
Type of knowledge	Q48	Incident information we receive suggests useful safety attitudes and values that can help us prevent future incidents.	0.82
	Q45	We receive information about incidents that allows us to understand what really happened and how we can learn from it.	0.82
	Q47	We know where to find relevant information regarding incidents so that we can prevent future similar incidents.	0.78
	Q46	The incident information we receive helps us understand which procedures we need to follow in order to prevent future incidents.	0.64
Formality of	Q31	Employees at this site make sure that important information	0.79

This paper was accepted for publication in Safety Science on 10 February 2017

This post-print (final draft post-refereeing) is released under 'Creative Commons Attribution, Non-Commercial, No Derivatives License'

learning		about incidents is shared with other employees who might benefit from it.	
	Q33	At this work-site, we discuss incidents and what to do to prevent them with our colleagues outside safety meetings and safety-specific communications.	0.76
	Q32	Information about incidents reaches all employees, even if they were away (off shift or on leave) when the incident information was disseminated.	0.75
	Q43	We inform the safety department about good ideas related to safety that arise from our informal discussions.	0.68
	Q42	We recognise when a piece of information about safety from our private discussions is important for the rest of the organisation.	0.67
	Q34	We hear about incidents through informal discussions with our colleagues rather than through formal safety information systems.	0.40*

The results of the mono-factorial scales indicate that two questionnaire items do not load well onto the designed factors: Q55 and Q34. These items were marked for further analysis. Table 7 illustrates the factor analysis results for the Learning process scale.

Table 7. Factor analysis of the Learning process scale

Items		**Factor loading**	
		1	**2**
Q23	Incident investigations are conducted in such a way that allows employees to be honest.	0.76	
RQ21	Incidents at our site do not get reported due to fear of negative consequences.	0.74	
Q24	We identify all the root causes of an incident before implementing further improvements.	0.66	
Q20	The management at our site consistently encourages reporting of incidents.	0.53	
Q37	We continually question incident information we receive.		0.75
Q54	Employees are informed about the outcomes of implementation of incident prevention recommendations/actions.		0.69
Q50	At this work-site, we consider if we need to change the way we conduct work based on the incident information we receive.		0.61
Q52	At our work-site, we learn from near misses and incidents.		0.60

All items loaded above the minimum set in the procedure (0.5) indicating that all items can be retained for the Learning process scale.

This paper was accepted for publication in Safety Science on 10 February 2017

This post-print (final draft post-refereeing) is released under 'Creative Commons Attribution, Non-Commercial, No Derivatives License'

Internal consistency

The reliability of the instrument was tested using Cronbach's alpha. Cronbach's alpha was calculated for each learning component scale as well as for each learning phase scale. We further analysed all items which did not meet an acceptable level of internal consistency (i.e. $\alpha < .70$). There was good overall reliability of the LFIQ scales (Part 2): Site 1: α=0.95; and Site 2: α=0.94.

Table 8 illustrates reliability results for the learning phase scales at both sites, while table 9 indicates the Cronbach's alpha values for the learning component scales. Scales that did not meet the minimum criteria detailed in the analysis section are marked with an asterix (*).

Table 8. Reliability of the learning phase scales at both sites

Learning phase scale	Number of items	Site 1			Site 2		
		n	%	α	n	%	α
Reporting	6	705	95.3	0.73	39	95.1	0.70
Investigating	3	720	97.3	0.80	40	97.6	0.72
Developing incident alerts	8	145	19.6	0.80	16	39	0.55*
Disseminating	9	708	95.7	0.85	40	97.6	0.71
Contextualising	16	689	93.1	0.90	40	97.6	0.91
Implementing actions	6	709	95.8	0.73	40	97.6	0.77

The Cronbach's alpha scores were acceptable (above 0.7) for all scales, except for the 'Developing incident alerts' scale at Site 2. However, this scale represents a branch of the questionnaire that was answered only by participants who actively develop alerts on the sites. This means that the number of respondents for the scale at Site 2 was small (n=16), so it was not possible to draw conclusions about the reliability of the scale at Site 2. Overall, the remaining learning phases' reliability results show good reliability at both Sites.

Table 9. Reliability of the learning component scales

Learning phase scale	Number of items	Site 1			Site 2		
		n	%	α	n	%	α
Type of problem	7	702	94.9	0.71	40	97.6	0.71
Learning process	10	687	92.8	0.83	39	95.1	0.79
Participants of learning	11	686	92.7	0.88	39	95.1	0.84
Type of knowledge	4	708	95.7	0.73	40	97.6	0.83
Formality of learning	8	688	93.0	0.74	39	95.1	0.65*

This paper was accepted for publication in Safety Science on 10 February 2017

This post-print (final draft post-refereeing) is released under 'Creative Commons Attribution, Non-Commercial, No Derivatives License'

Reliability tests across the learning component scales illustrated that all five learning component scales were reliable at Site 1. At Site 2 one of the five learning component scales (Formality of learning) did not result in the required level of reliability. By removing one item (Q34) the Formality of learning scale was tested within a satisfactory level of reliability (α=0.72). Although this reliability result was only shown for 39 responses at Site 2, Q34 was marked for further investigation in the factor analysis.

Inter-item correlations, and correlations between LFI components at both sites demonstrated significant relationships. While this was the case within each site, this did not translate to correlations across the two sites. This may mean that LFIQ items tap into the same underlying concept within each site, and therefore may be considered too narrow. This would be supported by the finding that LFI was largely mono-factorial.

4.3 Revisions to the LFIQ instrument

The reliability studies and the principal component analyses indicated that the instrument is reliable and valid; though four items (Q19, Q34, Q46 and Q55) required modification. Arguably, the decisions on problematic questions should also include feedback from the potential end users of the questionnaire. We therefore combined the suggestions from the focus groups with the results of the quantitative analyses in order to triangulate the data. In summary, we considered four criteria during the revision process:

1. The results of the reliability study

2. The results of the factor analysis

3. The feedback received from the focus group at Site 1

4. The feedback received from the focus group at site 2

Only when at least 2 of the 4 criteria are not satisfied was an item modified or removed. The integrated analysis resulted in three groups of items.

The first group comprised items which gave satisfactory results in reliability and factor analysis studies. Participants from both focus groups stated that these questions were clear. Table 10 offers an example of these questions. These items were retained in their original form. Unshaded cells indicate that a criterion was satisfied and white cells indicate that the criterion was satisfied.

This paper was accepted for publication in Safety Science on 10 February 2017

This post-print (final draft post-refereeing) is released under 'Creative Commons Attribution, Non-Commercial, No Derivatives License'

Table 10 Items that satisfied all criteria

Item	Factor analysis	Site 1 Focus group	Site 2 Focus group
Q32. Information about incidents reaches all employees, even if they were away (off shift or on leave) when the incident information was disseminated.	*Factor loading satisfactory*	Participants thought that the question was clear and that the results accurately represent the site.	Participants thought that the question was clear. A couple of participants were surprised that there were any negative responses to this question.
Q20. The management at our site consistently encourages reporting of incidents.	*Factor loading satisfactory*	Participants thought that the question was clear and that the results accurately represent the site.	Participants thought that the question was clear and that the results accurately represent the site.

The second group of items indicated problems in only one out of the four criteria. These items were also retained in the same format since problems in only one source do not justify modifying an otherwise valid item. Table 11 shows examples of items from the second group.

Table 11. Items that did not satisfy one criterion

Item	Site 1 Focus group	Site 2 Focus group
Q35. We consider if the incident information we receive is relevant to our own work.	Participants thought that the question was clear and that the results accurately represent the site.	A participant suggested using 'whether' instead of 'if' to clarify the question. Another participant thought that 'Consideration is given…' would be a better structure.
Q46. *The incident information we receive helps us understand which procedures we need to follow in order to prevent*	Participants thought that the question was clear and that the results accurately represent the site.	Participants thought that the question was clear and that the results accurately represent the site.

This paper was accepted for publication in Safety Science on 10 February 2017

This post-print (final draft post-refereeing) is released under 'Creative Commons Attribution, Non-Commercial, No Derivatives License'

The third group of items were the ones where at least two of the criteria were not satisfied and the question needed further modifying or removing. Table 12 indicates examples of these items.

This paper was accepted for publication in Safety Science on 10 February 2017

This post-print (final draft post-refereeing) is released under 'Creative Commons Attribution, Non-Commercial, No Derivatives License'

Table 12 Items that did not meet two or more criteria

Item	Reliability	Factor analysis	Site 1 Focus group	Site 2 Focus group	Decision
Q55. We follow the recommendations/actions in incident information without discussing them first.	α satisfactory	*Factor loading low: -0.193*	Participants thought the question was clear. Participants agreed with the results, noting that they did not discuss actions because they are discussed at a higher level.	The question was not interpreted as discussing how the action affects their work but was understood as discussing incident information with all relevant groups in the company.	Question updated to: *We discuss actions aimed at improving learning from incidents before we implement them.*
Q34. We hear about incidents through informal discussions with our colleagues rather than through formal safety information systems	*Reduced α at Site 2 for the Formality of learning scale*	*Factor loading low: 0.380*	The participants thought the question was clear.	The participants thought that there may be some misunderstanding whether they would be hearing about the incident for the first time as opposed to hearing about incident in general.	Question updated to: *Incident information reaches people at the site through formal processes rather than informally by word of mouth.*
Q19. At our workplace incidents are sometimes reported informally to colleagues without a formal record of the report.	α satisfactory	*Factor loading low: 0.373*	Participants pointed out that it is not clear whether colleagues are supervisors or co-workers. They implied that reporting to supervisors is already formal to an extent. All participants agreed that incidents and near misses have to be formally recorded in addition to reporting through the word mouth.	Although some participants though the question is clear, two participants thought the question is not clear and they were not sure whether to strongly agree or disagree. Participants agreed that reporting all questions formally is important and that the focus of the question could be rectified to address that.	Question updated to: *Incidents always get reported in the formal systems rather than informally to other workers.*

This paper was accepted for publication in Safety Science on 10 February 2017

This post-print (final draft post-refereeing) is released under 'Creative Commons Attribution, Non-Commercial, No Derivatives License'

5. Conclusions and future research

This paper outlined the development of an instrument to measure the quality of LFI processes and practices across an organisation or site. The Learning from Incidents Questionnaire (LFIQ) tested as valid and reliable for the reported sample. Items that tested as unreliable were redrafted or removed. Global analysis revealed one prominent factor that could measure the global quality of LFI at each site. The LFIQ components have equal importance and appear to tap into one underlying construct, which comprises knowledge processing and learning from incidents within organisations. Thus the LFIQ instrument questions represent a range of important components that comprise one single concept. The questions assigned to specific components appear to be of a similar nature, since the different items perform similarly within each component (Table 4).

To measure the quality of LFI across an industrial site it is useful to have a single instrument that measures the learning components and learning phases of LFI. Combining the learning component and learning phase perspectives of LFI into a single instrument can yield results with high reliability and validity. Viewing LFI from both the sequential perspective of learning phases and quality perspective of learning components is important in ensuring learning from incident initiatives are as effective as possible. The study also indicates that combining quantitative and qualitative data provides a basis for the development of an instrument that is valid in relation to the context it is used in. By gaining insight into employees' perspectives on LFI, companies can diagnose areas of LFI that need to be improved. Therefore, the LFIQ can be used in industry to identify the potential for improvement of LFI processes and practices, as well as further researching the relationships between elements of LFI and objective safety outcomes. While conceptually sound, there are some limitations to the methodology and analysis in this study. For example, though we recruited two sites to explore the validity of the LFIQ, most analysis, in particular the factor analysis were limited to the larger site 1. While we were able to control for possible organisational culture influences by avoiding to merge the data, there is a definite need to interrogate the factor structure of the LFIQ across different settings and contexts. This is particular important given the finding that LFIQ items tended to correlate with one another, suggesting that they all tap into one unifying concept, i.e. that of learning per se. While this is supported by the mono-factorial structure of the tool, the inter-item correlations may also flag up that the items are too narrow. Arguably, we did conduct expert interviews with practitioners to verify the nature and importance of LFIQ items included, however, the sample was small and cannot be regarded as representative nor generalizable. Further, future research should establish convergent validity by correlating the LFIQ with a questionnaire addressing a similar construct, if it is possible to identify an appropriate tool, such as the Organisational Climate for Learning from Errors at Work (OLE) questionnaire (Putz et al., 2013). The questionnaire could also be potentially limited by differences between espoused theories and theories-in-use. As noted by Argyis and Schön (1996), there is often a difference between official policies and what happens in reality. The questionnaire was designed with this in mind, and aims to measure the reality of a workplace; further studies focusing on consistency between the results of the questionnaire and other data sources could help to ensure that results do not just reflect hypothetical policies. Future research is needed to establish predictive validity and implementation fidelity to reduce incidents and accidents in hazardous workplaces.

This post-print (final draft post-refereeing) is released under 'Creative Commons Attribution, Non-Commercial, No Derivatives License'

Acknowledgements

This research was funded by the Energy Institute Hearts and Minds initiative. The authors would like to thank the Energy Institute for support and particularly Mr Stuart King for his input. We also thank Dr Germain Van Bever at the Open University for his help with the statistical analysis and Victoria Murphy for support with preparing the text.

References

Argyris, C., & Schön D.A. (1996). *Organizational learning II. Theory method and practice*. Reading: Addison-Weslay Publishing Company.

Barbaranelli, C. (2006). Analisi dei dati con SPSS. Milan: LED.

Billet, S., & Pavlova, M. (2005). Learning through working life: Self and individuals' agentic action, *International Journal of Lifelong Learning*, *24*(3), 195-211.

Buescher, M., Goodwin, D., & Mesman, J. (Eds.) (2009*). Ethnographies of diagnostic work: Dimensions of transformative practice.* Basingstoke: Palgrave Macmillan.

Chiva, R., Alegre, J., & Lapiedra, R. (2006, March). *Development and validation of an instrument to measure organizational learning capability.* Paper presented at International Conference on Organizational Learning, Knowledge, and Capabilities (OLKC), the University of Warwick, Coventry.

Cooke, D. L., & Rohleder, T. R. (2006). Learning from incidents: From normal accidents to high reliability. *System Dynamics Review*, *22*(3), 213-239.

Deloitte (2009). Mining safety. A business imperative. *Thought Leadership*. Johannesburg: Studio at Deloitte.http://old.cognitive-edge.com/wp-content/uploads/2010/10/101027-Deloitte-PoV-on-Mine-Safety-Feb09v2lowres.pdf.

Drupsteen, L., Groeneweg, J., & Zwetsloot, G. I. (2013). Critical steps in learning from incidents: using learning potential in the process from reporting an incident to accident prevention. *International journal of occupational safety and ergonomics, 19*(1), 63-77.

Easterby-Smith, M., Snell, R., & Gherardi, S. (1998). Organizational learning: Diverging communities of practice? *Management Learning*, *29*(3), 259-272.

Edmondson, A. (1999). Psychological safety and learning behavior in work teams. *Administrative science quarterly, 44*(2), 350-383.

Eraut, M. (2004). Informal learning in the workplace. *Studies in continuing education*, *26*(2), 247-273.

Fuller, A. & Unwin, L. (2004). Expansive learning environments: Integrating organizational and personal development. In H. Rainbird, A. Fuller and A. Munro (Eds.), *Workplace Learning in Context* (pp. 126-44). London: Routledge.

Gherardi, S., & Nicolini, D. (2000). To transfer is to transform: The circulation of safety knowledge. *Organization, 7*(2), 329-348.

This post-print (final draft post-refereeing) is released under 'Creative Commons Attribution, Non-Commercial, No Derivatives License'

Gorsuch, R.L. (1983). Factor Analysis (2nd ed.). Lawrence Erlbaum Associates, NY.

IBM Institute for Business Value (2009). *The enterprise of the future: IBM Global CEO Study - Telecom industry edition*. Available from http://www-935.ibm.com/services/us/index.wss/ibvstudy/gbs/a1031155?cntxt=a1000065

Jashapara, A. (2003). Cognition, culture and competition: An empirical test of the learning organization. *The Learning Organization*, *10*(1), 31-50.

Kletz, T. A. (2001). *Learning from accidents*. Oxford: Gulf Professional Publishing.

Kramer, D. M., & Cole, D. C. (2003). Sustained, intensive engagement to promote health and safety knowledge transfer to and utilization by workplaces. *Science Communication*, *25*(1), 56-82.

Kululanga, G.K., Price, A.D., & McCaffer, R. (2002). Empirical investigation of construction contractors' organizational learning. *Journal of Construction Engineering and Management*, *128*(5), 385-391.

Lähteenmäki, S., Toivonen, J., & Mattila, M. (2001). Critical aspects of organizational learning research and proposals for its measurement. *British Journal of Management*, *12*(2), 113-129.

Le Coze, J. (2008). Disasters and organisations: From lessons learnt to theorising. *Safety Science, 46*(1), 132-149.

Loud, J. J. (2004). Corrective action programs. *Professional Safety*, *49*(12), 32-45.

Lukic, D., Littlejohn, A., & Margaryan, A. (2012a). A framework for learning from incidents in the workplace. *Safety Science, 50*(4), 950-957.

Lukic, D., Littlejohn, A., & Margaryan, A. (2012b). Learning from incidents. *Petroleum Review, 66*(790), 36-37.

Lukic, D., Margaryan, A., & Littlejohn, A. (2010). How organisations learn from safety incidents: A multifaceted problem. *Journal of Workplace Learning, 22*(7), 428-450.

Lukic, D., Margaryan, A., & Littlejohn, A. (2013). Individual agency in learning from incidents. *Human Resources Development International, 16*(4), 409-425.

Lundberg, J., Rollenhagen, C., & Hollnagel, E. (2009). What-You-Look-For-Is-What-You-Find–The consequences of underlying accident models in eight accident investigation manuals. *Safety Science*, *47*(10), 1297-1311.Melo, S., & Beck, M. (2011). *Improving patient safety through formal and informal learning networks* (The York Management School No. 60). York: University of York.

Nassar-McMillan, S. C., & Borders, L. D. (2002). Use of focus groups in survey item development. *The Qualitative Report*, *7*(1), 1-12.

Nederhof, A. J. (1985). Methods of coping with social desirability bias: A review. *European journal of social psychology, 15*(3), 263-280.

Nichols-Nixon, C. (1997). Commentary: The importance of know-where and know-when. *Advances in strategic management*, *14*, 103-110.

This post-print (final draft post-refereeing) is released under 'Creative Commons Attribution, Non-Commercial, No Derivatives License'

Nielsen, M. B., Hystad, S. W., & Eid, J. (2016). The Brief Norwegian Safety Climate Inventory (Brief NORSCI)–Psychometric properties and relationships with shift work, sleep, and health. *Safety Science, 83*, 23-30.

Nielsen, K. J., Rasmussen, K., Glasscock, D., & Spangenberg, S. (2008). Changes in safety climate and accidents at two identical manufacturing plants. *Safety Science, 46*(3), 440-449.

Peterson, R. A. (2000). Asking specific questions. In *Constructing effective questionnaires* (pp. 83-100). Thousand Oaks, CA: SAGE Publications Ltd.

Olsen, W. (2012). Questionnaire design. In *Data collection: Key debates and methods in social research* (pp. 119-120). London, : SAGE Publications Ltd doi: 10.4135/9781473914230.n22

Oppenheim, A.N. (1996). *Questionnaire design, interviewing and attitude measurement.* London/New York: Pinter Publishers.

Phimister, J. R., Oktem, U., Kleindorfer, P. R., & Kunreuther, H. (2003). Near-miss incident management in the chemical process industry. *Risk Analysis, 23*(3), 445-459.

Putz, D., Schilling, J., Kluge, A., & Stangenberg, C. (2013). Measuring organizational learning from errors: Development and validation of an integrated model and questionnaire. *Management Learning, 44*(5), 511-536.

Rose, A. (2004). 'Free lessons' in aviation safety. *Aircraft Engineering and Aerospace Technology*, *76*(5), 467-471.

Sanne, J. M. (2008). Incident reporting or storytelling? Competing schemes in a safety-critical and hazardous work setting. *Safety Science, 46*(8), 1205-1222.

Slotte, V., Tynjälä, P., & Hytönen, T. (2004). How do HRD practitioners describe learning at work? *Human Resource Development International*, *7*(4), 481-499.

Snowden, D. (2002). Complex acts of knowing: Paradox and descriptive self-awareness, *Journal of Knowledge Management*, *6*(2), 100-111.

Stanton N. A., & Walker, G. H. (2011). Exploring the psychological factors involved in the Ladbroke Grove rail accident. *Accident Analysis & Prevention, 43*(3), 1117-1127.

Svensson, L., Ellström, P. E., & Åberg, C. (2004). Integrating formal and informal learning at work. *Journal of Workplace Learning*, *16*(8), 479-491.

Tynjälä, P. (2008). Perspectives into learning at the workplace. *Educational Research Review*, *3*(2), 130-154.

Weick, K. E., Sutcliffe, K. M., & Obstfeld, D. (2005). Organizing and the process of sensemaking. *Organization Science*, *16*(4), 409–421.

Wong, P. S., Cheung, S. O., Yiu, R. L., & Hardie, M. (2012). The unlearning dimension of organizational learning in construction projects. *International Journal of Project Management*, *30*(1), 94-104.

This paper was accepted for publication in Safety Science on 10 February 2017

This post-print (final draft post-refereeing) is released under 'Creative Commons Attribution, Non-Commercial, No Derivatives License'

Appendix A. Operationalisation of the *LFIQ concepts*

Learning component of LFI	Dimensions	Latent question	Relevant learning phase of LFI
Type of problem	*Considering complexity* Different learning approaches need to be considered depending on the complexity of an incident (Deloitte, 2009; Snowden, 2002).	*Is the same learning approach implemented for all types of incidents, regardless of their complexity?*	Developing incident alerts
			Disseminating
	Importance of context Some incidents are more complex than others. The solutions that prevent incidents in one context might not be relevant for another context. Solutions to prevent incidents should therefore be examined critically by employees when they receive incident information (Deloitte, 2009; Snowden, 2002).	*Is the local context of the workers considered when discussing learning points that arose from incidents in other settings/work contexts?*	Developing incident alerts
			Contextualising
			Implementing actions
	Collaborative sensemaking Sensemaking is a social process based on interactive communication. Therefore 'meaning' should be explicitly discussed so that employees have an *equivalent* (not necessarily the same) understanding of what happened and what needs to be done to prevent similar incidents from happening (Weick et al., 2005).	*Are sensemaking activities conducted collaboratively through voicing individual understandings?*	Investigating
			Contextualising
	Action oriented Sensemaking is action-oriented. Therefore, the discussions and collaborative interpretations in organisations should lead to concrete actions to improve safety (Weick et al., 2005).	*Are clear corrective actions developed in order to put learning from incidents into practice?*	Developing incident alerts
			Implementing actions
Learning participants	*Deciding on relevance* When developing and disseminating incident information, it is essential to consider who can benefit from incident alerts arising from that specific incident. Some incidents require dissemination of incident alerts to the whole site, some to only local groups and some to the wider industrial sector (Le Coze, 2008).	*Is the relevance of incident information actively considered in the LFI process?*	Developing incident alerts
			Disseminating

This paper was accepted for publication in Safety Science on 10 February 2017

This post-print (final draft post-refereeing) is released under 'Creative Commons Attribution, Non-Commercial, No Derivatives License'

Learning participants	*Communication* All workers that can benefit from LFI information should receive that information in a timely manner (Cooke & Rohleder, 2006).	*Do employees receive timely incident information through various LFI activities?*	Disseminating
			Contextualising
	Pathways for participation Employees should be treated as active learning agents rather than recipients of information. Therefore, employees should be encouraged to actively contribute to LFI (Billet & Pavlova, 2005; Fuller & Unwin, 2004).	*Is the LFI process allowing employees to contribute their ideas and offer feedback on incident information?*	Reporting
			Contextualising
	Giving input In addition to the company allowing and encouraging employees to give their input into LFI, employees should take that opportunity and offer their suggestions and feedback (Billet & Pavlova 2005; Loud, 2004)	*Do employees actively offer input to incident information?*	Contextualising
	Organisational response When employees understand the impact of their contribution to the LFI process, their motivation to engage with safety and LFI is significantly improved (Fuller & Unwin, 2004).	*Does the company respond to employees who have given feedback?*	Contextualising
			Implementing actions
Learning process	*Climate of openness* Double-loop learning requires a climate of trust in which employees can discuss incidents freely within an organisation (Kululanga, G.K, Price, A.D.F., & Macaffer, R., 2002; Rose, 2004).	*Can incidents be discussed freely without fear of the 'blame culture'?*	Reporting
			Investigating
	Commitment to learning The organisational commitment to LFIis an important element of double-loop learning. The organisations exibit their commitment to LFI through consistency between the declared learning goals and actual practice (Argyris & Schön, 1996; Kululanga et al., 2002).	*Is the company showing commitment to learning from incidents?*	Reporting
			Implementing actions
	Changing the governing values In order to achieve double loop learning, the organisation needs to aim at seeking and adopting improved management and working approaches through evaluation of current practice (Jashapara, 2003; Wong et al., 2012).	*Are employees questioning the way they conduct work when considering previous incidents?*	Contextualising

This post-print (final draft post-refereeing) is released under 'Creative Commons Attribution, Non-Commercial, No Derivatives License'

	Identifying the root of the problem The root causes that lead to an incident should be identified before deciding the actions that will be taken to improve the incident (Kletz. 2001; Kululanga et al., 2002; Wong et al., 2012)	*Are investigations conducted fully before future recommendations are implemented?*	Investigating
Type of knowledge	*Conceptual knowledge* Conceptual knowledge is important because it helps individuals understand the possible nature of an incident, and its relationship with other, associated work situations (Kramer & Cole, 2003).	*Is the conceptual knowledge overtly considered in the LFI process?*	Developing incident alerts
			Contextualising
	Procedural knowledge Understanding what procedures need to be followed or changed to prevent future incidents is a relevant aspect of LFI (Kramer & Cole, 2003).	*Is the procedural knowledge overtly considered in the LFI process?*	Developing incident alerts
			Contextualising
	Locative knowledge Employees should know where to find the knowledge they need to deal with safety incidents in the most effective manner (IBM Institute for Business Value studies, 2009; Nichols-Nixon, 1997).	*Is the locative knowledge overtly considered in the LFI process?*	Developing incident alerts
			Contextualising
	Dispositional knowledge The dispositions and safety values underpin the development of other types of knowledge. LFI should challenge employee's existing dispositions that may increase the risk of an incident. (Cooke & Rohleder, 2006).	*Is the dispositional knowledge overtly considered in the LFI process?*	Developing incident alerts
			Contextualising
Formality of learning	*Existence of informal communications* A great deal of discussions around incidents happen outside formal company systems through everyday work and private discussions. These activities provide an opportunity for informal learning from incidents (Deloitte, 2009; Eraut, 2004; Melo & Beck, 2011; Sanne, 2008).	*To what extent are opportunities for informal learning from incidents present at the site?*	Reporting
			Disseminating
			Contextualising
	Recognising learning potential of informal communications In order for relevant information from informal discussions to enter the formal structures the community needs to recognise learning potential of information and ideas and capture them for the rest of the organisation (Eraut, 2004; Melo & Beck, 2011; Tynjälä, 2008).	*Do employees recognize and capture relevant information from informal discussions related to incidents?*	Disseminating

This paper was accepted for publication in Safety Science on 10 February 2017

This post-print (final draft post-refereeing) is released under 'Creative Commons Attribution, Non-Commercial, No Derivatives License'

	Integrating informal learning Important ideas and information related to incidents are often overlooked by formal processes. It is important that possible suggestions, ideas and inputs from informal discussions enter the formal LFI system so that the rest of the company could benefit from them (Deloitte, 2009; Sanne, 2008; Slotte et al., 2004; Svensson et al., 2004; Tynjälä, 2008).	*To what extent do important information and ideas arising from informal discussions of incidents enter the formal LFI system?*	Contextualising
			Disseminating