Towards an Understanding of Learning within the Norwegian Fire and Rescue Services – Focusing on tunnel fire safety

Abstract

Purpose - The aim of this article is to study how learning within the fire and rescue services may be conceptualized, with special attention paid to tunnel fire safety. Previous studies have developed a model to understand learning in emergency response work. The concept of learning is extended from observed changes in relevant settings to also encompass confirmation of existing knowledge and comprehension of existing practices. We are interested in investigating the properties of the learning model and identifying the mechanisms that influence fire and rescue personnel's experiences of change, confirmation and/or comprehension.
Design/methodology/approach - This study relies on quantitative data obtained from a questionnaire answered by 939 Norwegian fire and rescue personnel. Multivariate methods have been employed to identify the measurement model and the structural relations of the factors.
Findings - Results confirm the theoretical model and indicate that the *outcome of learning* is influenced by elements of *content*, *context*, *commitment*, *decision-making and response* and *reflection* and that the influence of content and commitment on the outcome of learning is partially indirect and mediated through reflection.
Originality/value – To date, no systematic analysis has been conducted to investigate the factorial structure, as well as the interactions and relationship between the model's components. This study makes an important contribution to a detailed understanding of learning within the fire and rescue services.

Keywords Experiential learning, Reflection, Fire and rescue services, Tunnel fire safety, Structural equation modelling

Paper type Research paper

1. Introduction

This article provides results from evaluating a model for learning in workplace that was developed for personnel working in emergency response services. Learning within the fire and rescue services is mainly experienced-based and on-the-job training and takes place through means quite distinct from learning that occurs in formal educational settings (Aase and Njå, 2004; Rake, 2008). Workplaces are considered legitimate learning spaces with pedagogical properties, consisting of highly structured activities and interactions (Billett, 2004). Nevertheless, within the context of fire and rescue services, there is a lack of understanding regarding how fire and rescue personnel learn, what they learn and when (Sommer and Njå, 2011). Fire and rescue personnel acquire much of their knowledge and skills through socially constructed workplace practices and experiences, e.g., responses to incidents, activities between responses, participation in organized educational programmes and training exercises. Currently, the fire departments have a high degree of freedom to implement learning activities within their workforce (Bjørnsen and Njå, 2019). Their interpretations of the needs, contents and instructional techniques vary substantially. The workplace learning is an inherent part of the various fire departments but is rarely reflected in terms of how it contributes to learning and the subsequent levels of competencies.

Traditionally in workplace, formal learning is often contrasted with informal learning (Eraut, 2000; Malcolm et al., 2003). Although formal and informal learning are presented in contrast, both types of learning should be considered as essential components of workplace learning and treated as complementary (Slotte et al., 2004). This study addresses workplace learning as formal and informal learning embedded in fire and rescue personnel's conscious cognitive activities and their everyday work practices (Billett, 2004; Hager, 2011; Lave and Wegner, 1991). Further, competence is understood as fire and rescue personnel's knowledge and skills necessary to handle relevant, but often unforeseen, unpredictable and challenging situations (i.e. tunnel fire responses) (Illeris, 2011).

In workplace, how to understand and integrate learning with work tasks is a key issue (Ellström, 2001). Recently, research on different aspects of learning within the fire and rescue services has increased. For instance, Dekker et al. (2008) studied the ability of fire departments to learn during emergency responses and found that they often lacked basic organisational prerequisites for effectively learning from failures, e.g., mutual trust, participation, knowledge of possible learning mechanisms. In their study of learning amongst Norwegian fire fighters, Sommer and Njå (2011) concluded that learning can be improved by actors becoming more reflective practitioners. Furthermore, to enhance the embodiment of skills and knowledge, the fire departments should facilitate systematic sharing of experiences and development of more challenging training exercises that gives the opportunity to understand how and why the current practices are meaningful in critical situations.

One of the most important purpose of understanding learning in workplace is to systematically organize, update and develop vocationally oriented education and personnel's competencies (Illeris, 2011). Illeris claims that it is easier and more efficient if the development of competence is to take place where the competence is to be utilized and there where new and first-hand knowledge is always available. Switzerland developed their own tunnel fire safety academy (IFA) after the devastating fire in the St. Gotthard tunnel in 2003 (Voeltzel and Dix, 2004). The IFA includes two locations in Switzerland with tunnel facilities to combat fires and carry out rescue activities in controlled environments. It is a mandatory part of the Swiss firefighting education to complete and pass courses at the IFA.

How to best understand learning is a matter of concern amongst educators and practitioners. The local fire departments need to provide the necessary capabilities to respond adequately to complex situations; thus, awareness about how to best structure and develop learning to increase learning outcomes is a prerequisite. The situation in Norway and in Europe is unclear. A starting point is to conceptualise learning and contributing factors. To address this issue, the study reported in this article adopts the learning model developed by Sommer, Braut and Njå (2013). This is the first article that examines the factorial structure of the model and describes the direct and indirect effects between its components. An evidence-based model is essential for grasping the aspects that need to be considered to understand learning within the fire and rescue services. Thus, the study has two main goals: (1) to assess Sommer et al.'s theoretical model in the empirical context of Norwegian fire and rescue services; (2) to offer guidance to decision makers on how to effectively design and implement learning. The model may be regarded as a way of providing an overview of what fire and rescue personnel regard as central aspects in connection with learning and as a guide in the context of planning, implementing, and evaluating learning within the fire and rescue services.

1.1.Perspectives on experiential and workplace learning

Within the modern understanding of learning from experience, John Dewey’s voice has been one of the most prevalent on matters of experience. For Dewey, who placed a great deal of importance on the value of shared, interactive experience, thinking and knowledge acquisition

cannot be separated from the world in which we live (Roberts, 2012). *It is in the interaction between the two, and how the two revise each other, that brings about new awareness and learning* (p. 51). The social construction of experience, e.g. in workplace practices, is assumed to be realized between thinking and doing, in a continuous interaction between the individual and the world (Hohr, 2013). Dewey claimed that learning from experience occurs when learners attempt to solve real problems. However, this requires *both action in the form of doing in the world and reflection in the form of cumulative and contingent knowledge gained over time* (Roberts, 2012, p. 54). Schön puts weight on the qualified practitioner's ability to reflect upon their own learning processes in action (Schön, 1991). Combining new information and observations with the relevant contextual elements and approaching this through more or less conscious and structured reflection is an important way of learning amongst professional practitioners.

In research on experiential learning, two main trajectories can be identified: one analyses the mechanisms of learning as a psychological phenomenon, and the other requests historical and social critical analyses as a fundamental approach (Seaman et al., 2017). In recent decades, several models seeking to understand how individuals learn in workplace have been launched (Illeris, 2004; Kolb, 1984; Sommer et al., 2013). The models have mainly been motivated from theories and related indirect empirical data. In many cases, specific studies to challenge theories and models are lacking.

Kolb's (1984) experiential learning cycle remains the most widely used model of experiential learning theory. The model theorizes that learning is an ongoing circular process, transforming concrete experiences through reflection, the forming of mental models and the testing of conclusions. The combination of experience, perception, cognition and behaviour provides a holistic integrative learning perspective, in which learning is conceived as a complex process rather than distinct behavioural outcomes (Kolb, 1984). In line with this, learning and experience is reduced to a rational, excessively cognitive and individual phenomenon (Seaman, 2008). In Scandinavia, one of the most prominent models of learning in the workplace is presented by Illeris, who bridges the two approaches (Illeris, 2004; 2011). He claims that learning involves a) an external interaction process between the learner and his/her social, cultural and material environment, and b) an internal psychological process of elaboration and acquisition. For Illeris, experiential learning points to the necessity of considering the connection between the learner and the content, the kind of interest and motivation that is involved and the kind of activity that is likely to engage the learner in the topic or skill the learning is about.

In Braut and Njå's (2009) and Njå and Braut's (2010) conceptual framework of learning in emergency response settings, an experiential model is proposed from an *individual cognitive approach to learning* and a *socio-cultural approach to learning.* The latter focuses on learning as participation and explains the development of competence through contextual factors. Especially in workplace, the two approaches complement each other (Billett, 2001; Illeris, 2011) and must be combined to fully understand how emergency personnel develop competence and vocational expertise (Sommer et al., 2013; Sommer and Njå, 2011). Traditionally, learning is understood as observable changes in workplace behaviour (Argyris and Schön, 1996). This study adopts a broad concept of learning, where learning is understood as the *processes related to establishing new knowledge aiming to implement changes to, gaining deeper comprehension of and/or confirming the basis for, current apprehensions and practices* (Njå and Braut, 2010, p. 43).

1.2. The learning model

The process model depicted in Figure 1 is evaluated in this article. The model sees learning as a continuous process, involving six interrelated concepts: *content*, *context*, *commitment*, *decision-making and response*, *reflection* and the outcome of learning expressed as *change*, *confirmation* and/or *comprehension*, which again affects *content, context* and *commitment* on a higher level (Sommer et al., 2013).

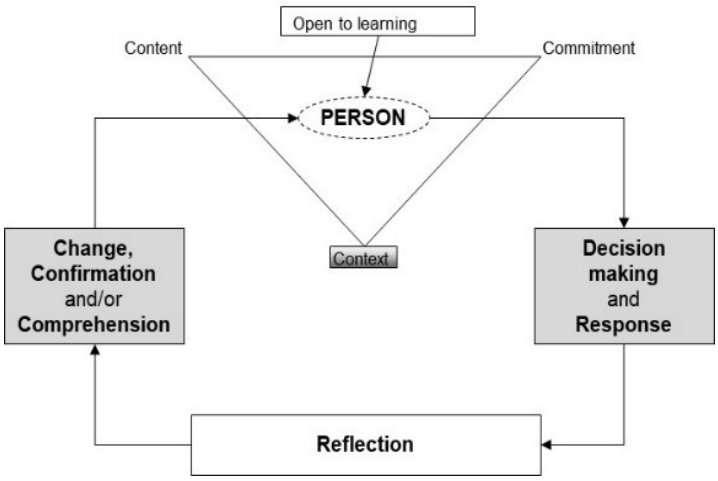

Figure 1. Learning model based on Sommer et al. (2013)

A competent practitioner is considered able to repeat what can (and should) be repeated while changing what needs to be changed (Sfard, 1998). Learning outcomes have generally been expressed as *changes* in structure, behaviour, cognition, processes or organizations. This is an observable feature; however, learning also includes features which are less observable but equally important as concrete changes in behaviour. Learning comprises *confirmation* of existing knowledge and practices and *comprehension* of established practices, behaviours or working methods (Sommer et al., 2013). Confirmation refers to a kind of positive reinforcement, verifying that the fire and rescue personnel's beliefs and practices for approaching emergency situations are appropriate. Comprehension is achieved when the personnel gain a deeper understanding of the practices and behaviours necessary to cope adequately with incidents.

The individual firefighter, the teams involved in tunnel fire responses or the entire emergency service systems need to reflect upon stimuli and inputs gained from experience. *Reflection* is the processing phase, in which individuals consciously think about a concrete experience, assess what happened and evaluate the response (Boud et al., 1996; Brookfield, 1998). Within the fire and rescue services, experience may be acquired through formal learning activities (e.g., workshops, seminars, fire drills), or it could be of a more informal character (e.g., an incident or other unplanned event occurring in daily work settings, discussions with colleagues during gatherings, debriefing after exercises). During gatherings, personnel discuss common problems, and gaining other perspectives on a particular problem expands the possibility of coming across an interpretation that fits the situation. The accumulated experiences may provide new understandings that may eventually challenge and change their current judgements and practices. Reflection may occur at both the conscious and unconscious levels, and individuals' reflective capacity is assumed to be decisive for the ability to learn effectively from an experience (Boud et al., 1996). Our research conceptualizes reflection through examining the extent to which fire and rescue personnel jointly discuss their interpretations of the problems and assumptions that frame how they work.

However, reflections require active behaviour that might trigger either mental simulations or actions in real contexts. *Decision-making and response* relate to fire and rescue personnel's performances in real and training situations (Sommer et al., 2013). Decision-making within the emergency response context comprises activities such as determining goals and needs, scanning options, imagining consequences, conducting trade-offs and predicting obstacles to implementation (Klein, 2015). During training exercises and incidents, personnel engage in different types of behaviour and response actions, which are the result of information processing, situational awareness and decisions made. Consequently, the decisions form the outcome of the situation. Decision-making and response is therefore defined in terms of experience of real incidents in tunnels, based on the idea that involvement in incidents fosters decisions and, subsequently, response actions.

This brings us back to the stimuli situations, the concrete exercises, the taught materials, the involvements of learners, etc. Learning is formed by the individual placed between elements of *content*, *context* and *commitment*. Learning requires that those who are about to learn direct their attention towards something. This something is the *content* of what is being taught and must be experienced as relevant, to facilitate learning and improve fire and rescue personnel's problem-solving abilities and performances during responses to incidents. The idea is that it should comprise specific skills and behaviours that should be learned, and it is assumed to be of prime importance to motivate learners and lead them to be able to successfully cope with the problems of their respective disciplines (Levy, 1966). The practical and theoretical content of the learning activities should, therefore, emphasize topics seeking to develop skills and behaviours that the personnel must possess to deal effectively with incidents in tunnels (e.g., situational assessment, decision-making and responsibility, motor vs cognitive collaboration behaviour, flexible vs standardized cooperative behaviour, communication challenges). In this study, the content represents the totality of what is being taught and refers to facts, principles and concepts taught during learning situations (e.g., fire and smoke development, decision-making and allocation of responsibilities, human behaviour in crisis, extinguishing methods, risk related to response operations, search methods, coping with uncertainties).

Another key aspect of the learning process is the *context* in which learning takes place and the possibilities for learners' *commitment* to learning activities (Sommer et al., 2013). The importance of understanding individuals' behaviour and thinking, as situated in context, has been emphasized by researchers through the past decades (Pintrich, 2000; Wenger, 2009). This development is partially embedded in approaches that have stressed the inherently social nature of learning (Lave and Wenger, 1991). It is acknowledged that the role of context is to enable learners to develop practices within a community (Wenger, 2009). However, several conceptual and methodological implications arise, including what represents the context, how it can be operationalized and how to investigate its significance. Previous research related to learning within the fire and rescue services has defined contextual features as the physical, mental and emotional requirements of joint forces, contact with physical energy and training arenas (Bjørnsen et al., 2020). In light of the above, we approach the context through an examination of the prevailing emergency management exercises within the fire and rescue services (e.g., table-top, functional, full-scale). The exercises involve cooperation between personnel at different levels in one or several organizations and are executed in specific learning environments (e.g., indoor – classrooms vs outdoor – in the field).

Furthermore, effective learning must be built on processes that are conceived as meaningful by learners, and individuals' commitment to learning activities strongly influences what and how much learning occurs (Sommer et al., 2013). Commitment refers to learners' involvement in learning activities and has been acknowledged as a necessary condition for learning (Skinner et al., 2008). For this study, we look upon commitment as affective components within learners,

reflecting motivations, relevance and the stimulation of new thinking. Investigating these effects provides insight into the extent to which fire and rescue personnel's emotional states during learning, such as their enthusiasm, creativity and interest, play a role in their achievement of learning outcomes.

In this study, we confront the theoretical learning model of Sommer et al. (2013) with work-place practices in the empirical context of the Norwegian fire rescue services and examine the structural relations between these above-mentioned components.

2. Materials and Method

2.1. The questionnaire

Building on Braut and Njå's (2009) and Njå and Braut's (2010) theoretical framework of learning, the Handbook for Exercise Planning (Vik et al., 2014), the textbook Firefighting Operations in Road Tunnels (Brauner et al., 2016) and discussions with tunnel experts, we developed a questionnaire with Sommer et al.'s (2013) six dimensions of learning, comprising 28 items. The research instrument consisted of a larger series of questions, which are not discussed in this paper. Before the content and design of the initial version of the instrument was established, different pre-tests of the instrument were performed and discussed between the authors and an expert panel composed of 16 representatives of the target group. The evaluation focused on the clarity of the questionnaire and its measures. Comments were sought on confusion about terminologies and the meaning of questions asked, and corrections were made accordingly. However, a formal validation of the scale has not yet been performed. The current data are obtained with the preliminary questionnaire. For more details, see Supplementary Materials, Table SI.

2.2. Sampling procedures

All fire and rescue chiefs with tunnels longer than one kilometre in their area of responsibility were approached by email, and the data was collected by means of a web-based questionnaire. Eligible respondents were further selected by the fire and rescue chiefs, based on the criterion that tunnel fire safety constituted a major part of their occupational tasks. The first part of the data was collected between March and June 2019 and consisted of 750 responses. However, we still lacked participation from four fire departments responsible for many complex tunnels in their regions. Considering that those fire departments were located in counties with a high density of tunnels (Hordaland, Møre og Romsdal, Sogn og Fjordane and Nordland), we decided to visit them to ensure participation in the study. By the end of September 2019, we had succeeded in collecting an additional 189 responses.

2.3. The sample

In total, 939 participants answered the survey, yielding a response rate of 48.5%. Of the participants, 290 answered only some of the questions, while 649 completed the survey. However, the 290 participants provided important information related to their vocational education and their role in the fire department and were therefore not excluded from that part of the analysis. The reasons indicated for not completing the questionnaire were: (a) the respondents did not have sufficient knowledge to answer the section where they were asked to describe the tunnels at risk in their region, and (b) the respondents did not have any experience with tunnel fire safety learning activities.

In our study sample, 96% were men and 4% women, 61% were employed in full-time and 39% in part-time positions. The average age was in the 40-49 years category, with an average of 11-15 years of firefighting experience. All Norwegian counties were represented, with the highest number of respondents in the south-western part of the country. More precisely, four counties

accounted for 56% of the responses, respectively: Rogaland 20%, Hordaland 14.5%, Møre og Romsdal 12.5% and Sogn og Fjordane 9%. These are also the counties with the longest and the highest density of tunnels on the Norwegian road network. Most of the respondents were employed in full-time (47%) and part-time fire departments with on-call duty (27%). Hence, the sample is broadly representative of the Norwegian firefighting workforce.

2.4. Analytical approach

In order to deal with the challenges of factorial problems before analysing the structural relations, the measurement model was estimated and evaluated separately from the structural model (Bollen and Long, 1993). Multivariate methods were employed to identify the measurement model and examine the factor structure of the questionnaire, using the Mplus 8.6 program (Muthén and Muthén, 1998-2017). For more details, see Supplementary Materials, sections 1.2 and 2.1. The structural relations between the factors were analysed by means of structural equation modelling (SEM). Here, the constructs, *content*, *context*, *commitment*, *decision-making and response*, as well as *reflection*, were defined as latent explanatory variables, and the *outcome of learning* was defined as a latent dependent variable.

A key element when applying multivariate methods is to assess whether the model produces an estimated covariance matrix consistent with the sample matrix (Tabachnick et al., 2007). This consistency was investigated through various measurement indices of goodness of fit, such as Comparative Fit Index (CFI), Tucker-Lewis Index (TLI), Root Mean Error of Approximation (RMSEA) and Standardized Root Mean Square Residual (SRMR). Good model fit is indicated by a value below .05 on the RMSEA and SRMR and above .95 on the CFI and TLI (Browne and Cudeck, 1992).

3. Results

3.1. The measurement model

Based on theoretical assumptions about a particular factor pattern associated with Sommer et al.'s (2013) learning model, confirmatory factor analysis (CFA) with continuous factor indicators was conducted, to assess the extent to which the organization of the identified factors fits the model. Except for the variables measuring the dimension of decision-making and response, which was estimated with categorical indicators, all variables were measured on a continuous scale. A preliminary analysis identified that the variables included in this dimension caused challenges for the model to be identified. Investigation of the descriptive statistics showed skewed values and small variance in the items loading on this factor. An explanation is that Norwegian fire and rescue services have limited experience of major incidents in tunnels, and that only a minority of the respondents have acquired experience in such incidents. Researchers, especially in social sciences, often have to work with observed variables that can only take a limited number of values and are therefore willing to make certain simplified assumptions about a measurement scale (Rhemtulla et al., 2012). A frequently used assumption is that underlying each categorical variable is a normally distributed continuous variable, and the measurement model describes the relationship between the variables and the latent factors (Muthén, 1993). In social sciences, the existence of underlying continuous variables is a common assumption when analysing categorical variables, and this is the paradigm adopted in this study.

According to the underlying theory driving the research, a six-factor solution was proposed for the measurement model. The CFA model has been evaluated according to the strength and significance of factor loadings, the variance of latent variables and error terms. Tables I and II show the items that made up the dimensions, with the associated factor loadings for the hypothesized learning model.

During the CFA process, the measurement model was further modified, based on both statistical and theoretical assumptions: we reduced statistical redundancy in the determination of the individual factors, by eliminating some items based on modification indices. Moreover, since factors 1-5 are conceptualized as predictor variables and factor 6 as an outcome variable, we split the CFA for predictor and outcome variables respectively, as shown in Tables I and II.

Table I

Factor structure of the CFA predictor model and standardized factor loadings

Items	**Factor loadings**				
	Content	Context	Commitment	Decision-making and response	Reflection
Fire and smoke development	**0.536**				
Decision-making and allocation of responsibilities	**0.719**				
Human behaviour in crises	**0.714**				
Extinguishing methods	**0.719**				
Risk related to response operations	**0.743**				
Search methods	**0.730**				
Coping with uncertainties	**0.804**				
Motivational for my work tasks			**0.921**		
Relevant to my work tasks			**0.920**		
Stimulating new thinking about my work tasks			**0.856**		
Seminar/workshop		**0.871**			
Table-top		**0.934**			
Role-play		**0.882**			
Traffic accidents and rescue operations				**0.651**	
Tunnel fire rescue and extinguishing operations				**0.749**	
Dangerous goods operations				**0.350**	
Discussions of the learning content					**0.856**
Discussions under gatherings					**0.832**

Table II

Factor structure of the CFA predicted model and standardized factor loadings

Items	**Factor loadings**
	Learning outcome
Change	**0.824**
Confirmation	**0.890**
Comprehension	**0.901**

The analysis resulted in a model structured of five plus one dimensions, comprising 18 + 3 items assumed to influence the process of learning and its outcomes. CFA fit statistics also indicated that the suggested model fits to the data. The fit measures were: Chi-Square = 240.429, CFI = 0.982, TLI = 0.978, RMSEA = 0.035 and SRMR = 0.033 for the predictor model, and Chi-Square = 0.000, CFI = 1.000, TLI = 1.000, RMSEA = 0.000 and SRMR = 0.000 for the predicted model. Moreover, all factor loadings of the measured variables were significant ($p < 0.001$), indicating that the latent variables are adequately represented by the observed variables. Consequently, we considered the measurement model to present a good fit and used the proposed measurement model to examine the structural model.

The first dimension is entitled *Content* and comprises a total of seven items reflecting topics taught during learning activities. The second factor consists of three items associated with learning environments and represents the *Context*. The third factor is *Commitment* and consists of three items. This dimension reflects involvement in learning activities in terms of motivation, relevance and new thinking. The next dimension is *Decision-making and response* and consists of three items reflecting experience of incidents in tunnels. The fifth dimension is named *Reflection* and reflects activities associated with thinking or reflecting about acquired experiences. Lastly, the dimension of the predicted model includes three items that refer to the *Outcome of learning*.

3.2. The structural model

Through SEM, it is possible to answer questions of prediction and assess the fit of theoretically derived predictions to the data (Kelloway, 2014). The structural model was employed to examine which components of Sommer et al.'s (2013) learning model have a significant impact on the outcome of learning and how the outcome of learning is affected by the model's components. We conceptualized a model, hypothesizing that *reflection* is predicted by elements of *content*, *context*, *commitment*, *decision-making and response*. Further, the *outcome of learning* was hypothesized to be predicted by *content*, *context*, *commitment*, *decision-making and response* and *reflection*. The model was tested for indirect effects, by investigating whether *reflection* mediates the relationship between the *outcome of learning* and elements of *content*, *context*, *commitment* and *decision-making and response.* The significance of the indirect effects was tested through bootstrapping analysis (MacKinnon et al., 2007), requesting 1000 bootstrapped samples. The fit indices for the model yielded a good fit to the data: Chi-Square = 320.857, CFI = 0.982, TLI = 0.978, RMSEA = 0.034 and SRMR = 0.032. The standardized estimates for the hypothesized model and the correlation matrix for the latent variables are presented in Table III and Table IV.

Table III
Estimated correlation matrix for the latent variables

Content	1.000					
Context	0.210***	1.000				
Commitment	0.637***	0.254***	1.000			
Decision-making and response	-0.174**	-0.094	-0.128**	1.000		
Reflection	0.684***	0.222***	0.659***	-0.179**	1.000	
The outcome of learning	0.683***	0.285 ***	0.704***	-0.223***	0.768***	1.000

Notes. ***Correlation is significant for =.001 level (two-tailed); **Correlation is significant for 0.01 level (two-tailed); *Correlation is significant for 0.05 level (two-tailed).

As shown in Table III, except for the dimension of *decision-making and response*, which is insignificantly related to the dimension *context*, all other correlations are statistically significant. While the strongest correlations for the latent factors are observed for the dimensions of *reflection*, *commitment* and *outcome of learning*, the weakest correlations are observed for the dimensions of *context* and *decision-making and response*. For instance, *decision-making and response* is negatively and weakly correlated with *content* ($r = -0.174$, $p < 0.01$), *commitment* ($r = -0.128$, $p < 0.01$), *reflection* ($r = -0.179$, $p < 0.01$) and *outcome of learning* ($r = -0.223$, $p < 0.001$). Furthermore, *outcome of learning* is moderately to strongly correlated with *content* ($r = 0.683$, $p < 0.000$), *context* ($r = 0.285$, $p < 0.000$), *commitment* ($r = 0.704$, $p < 0.000$), *decision-making and response* ($r = -0.223$, $p < 0.000$) and *reflection* ($r = 0.768$, $p < 0.001$). All correlations were in the expected direction.

Table IV
Standardized results for the effects of the exogenous variables on the endogenous variables

Reflection	**β**	**S.E.**	**p**	**R^2**

Content	0.433	0.057	0.000***	
Context	0.032	0.043	0.455	
Commitment	0.368	0.057	0.000***	
Decision-making and response	-0.054	0.046	0.239	
				0.555
The outcome of learning				
Content	0.187	0.053	0.000***	
Context	0.074	0.034	0.027*	
Commitment	0.272	0.059	0.000***	
Decision-making and response	-0.072	0.037	0.050*	
Reflection	0.431	0.066	0.000***	
				0.687

Notes. β = standardized regression coefficient, S.E. = standard error, p = p-value for the test. ***Correlation is significant for =.001 level (two-tailed); **Correlation is significant for 0.01 level (two-tailed); *Correlation is significant for 0.05 level (two-tailed).

Based on Braut and Njå's (2009) and Njå and Braut's (2010) theoretical framework of learning, we expected all measurement scales to have a relatively moderate impact on the outcome of learning. Further, the hypothesized model affords the dimension of reflection a central position in predicting the outcome of learning. The assumed relationship is justified through the idea that reflection is a form of response by learners to an experience (Boud et al., 1996). The experience may be provoked by external agents arising out of the content of what is being learned or of the context where learning takes place. The experience may also have an internal character arising out of learners' possibility of commitment to learning activities or of performance exhibited during response operations.

Results from the analysis, as shown in Table IV, indicate that *reflection* is positively associated with the *content* of what is being learned ($\beta = 0.433$, $p < 0.001$) and by learners' *commitment* to learning activities ($\beta = 0.368$, $p < 0.001$). Further, the *outcome of learning* is positively associated with the *content* of what is being learned ($\beta = 0.187$, $p < 0.001$), the *context* in which learning takes place ($\beta = 0.074$, $p < 0.05$), learners' *commitment* to learning activities ($\beta = 0.272$, $p < 0.001$) and *reflection* ($\beta = 0.431$, $p < 0.001$). We see that *decision-making and response* is negatively associated with ($\beta = -0.072$, $p < 0.05$) the *outcome of learning*. This means that respondents that have not yet acquired experience in responding to incidents in tunnels report limited benefits from the learning activities. This model accounted for 68.7% of the variance.

Table V
Standardized results for the specific indirect effects of reflection on the outcome of learning

Reflection	**β**	**S.E.**	**p**
Content	0.187	0.037	0.000***
Context	0.014	0.020	0.478
Commitment	0.159	0.037	0.000***
Decision-making and response	-0.023	0.022	0.282

Notes. β = standardized regression coefficient, S.E. = standard error, p = p-value for the test. ***Correlation is significant for =.001 level (two-tailed); **Correlation is significant for 0.01 level (two-tailed); *Correlation is significant for 0.05 level (two-tailed).

Further, the model hypothesized the *outcome of learning* to be indirectly associated with elements of *content*, *context*, *commitment* and *decision-making and response*, and it assumes that the dimension of *reflection* mediates these effects. Mediation exists when a predictor variable affects a dependent variable through at least one intervening variable or mediator (Preacher & Hayes, 2008). Results presented in Table V show only two statistically significant ($p < 0.001$) paths of mediating effects of the dimension of *reflection* on the *outcome of learning*. The effects of the *content* of what is being learned ($\beta = 0.187$, $p < 0.001$) and of learners' *commitment* to learning activities ($\beta = 0.159$, $p < 0.001$) are mediated by *reflection*. We notice

that the total effect of *content* (β = 0.373) and *commitment* (β = 0.431) on the *outcome of learning* increases substantially when *reflection* is added to the equation. These results support our hypothesized model and demonstrate the importance of reflection in the learning process. Figure 2 depicts the relationships of the variables in the hypothesized model with the standardized path coefficients.

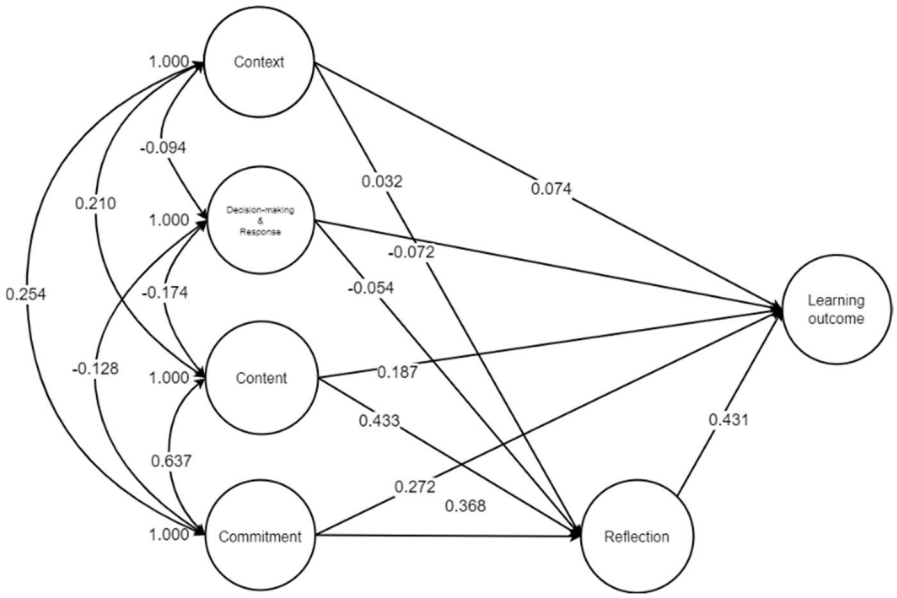

Figure 2. The structural equation model for the estimation of the relations between the latent variables

In general, the structural model corroborated the validity of the hypothesized relationships in the model. Except for the paths linking the *context* of learning and *decision-making and response* to *reflection*, all paths showed significant p-values ($p < 0.001$; $p < 0.05$) for direct and indirect effects on the *outcome of learning*. Based on theoretical considerations, we expected to find indirect paths also for the *context* of learning and for *decision-making and response* with *reflection*. Surprisingly, the mediating effect of *reflection*, through the *context* of learning and *decision-making and response*, on the *outcome of learning* was not statistically significant.

In our assessment, we suspect that the item's design characteristics, included in the dimension of context and decision-making and response, potentially cause difficulties by involving inaccurate measurement scales. Although the items comprising the dimension of context relate to different learning environments, they seem, rather, to measure the effectiveness of the didactical methods used in emergency response work. Further, the items constructing the dimension of decision-making and response concern experience of incidents in tunnels and relate only indirectly to decision-making and response during incidents. This should be worked with in future research studies, by enhancing the quality of the items included in these two dimensions of the model.

4. Discussion

This article provides evidence that the conceptual framework of learning in emergency response settings (Braut and Njå, 2009; Njå and Braut, 2010; Sommer et al., 2013) offers a valid way of understanding learning within the Norwegian fire and rescue services. Through the analysis, we have examined how experiences of change, confirmation and/or comprehension occur amongst fire and rescue personnel. The investigation has linked the learning model, as described by Sommer et al. (2013), with the empirical findings from the national survey. The

data obtained yields further and more detailed evidence of the theoretical model's contribution to understanding learning in emergency response settings and may be used to design educational programmes and learning activities aimed at enhancing fire and rescue personnel's competencies. Through the structural model, we have investigated a postulated connection between fire and rescue personnel's experiences of change, confirmation and/or comprehension and the content of what is being learned, the context where learning takes place, learners' commitment to learning activities, decision-making and responses during incidents and reflection. The dimension of reflection was assumed to mediate the relationship between the model's components on the outcome of learning. The rationale behind is that, for learning to occur, it is not sufficient that fire and rescue personnel simply have an experience. Without reflecting upon the acquired experience, the learning potential may be lost, and the experience may remain only as experience. Reflection is thus a necessary stage in the learning process, occurring after other substantial activities have taken place (Boud et al., 1996). In addition, consistent with prior research (Sommer et al., 2013), reflection permeates every stage of the learning process – from learner's choice to involvement in a particular learning activity to the ultimate results of the process.

As expected, in line with Sommer et al.'s (2013) model of learning, we notice that the dimension of reflection has the strongest impact on the outcome of learning. For fire and rescue personnel to learn from experiences, they need to reflect upon the choices open to them at the time and the suitability of the decisions made and actions taken. By critically appraising what has been experienced, fire and rescue personnel may use the information and knowledge they are gaining to improve/change behaviours and working methods, confirm ongoing practices and knowledge and/or develop more comprehensive understandings of specific phenomena. However, we find it puzzling that the outcome of learning is weakly associated to the context of learning and to decision-making and responses to incidents. Although our study did not assume these dimensions to be primary predictors for the outcome of the learning process, researchers have emphasized the importance of context (Wenger, 2009) and of decision-making and response (Klein, 2015; Sommer and Njå, 2011) for learning outcomes.

The most remarkable finding is that, while the effect of content and commitment on the outcome of learning is mediated through reflection, the effect of context and decision-making and response on the outcome of learning is direct and insignificantly related to reflection. We suspect that a probable reason for this inconsistency is that the items of the questionnaire used to conceptualize the dimension of context and decision-making and response did not capture the actual dimensions presented in the learning model. The fact that these dimensions made only marginal contributions as predictors and that their effects are not mediated through the dimension of reflection does not fully correspond with the theoretical framework on which Sommer et al.'s (2013) model of learning is built. It appears that the measurement scales used to capture the dimension of context, rather, measure fire and rescue personnel's assessments of the efficacy of didactical methods and not the various training arenas associated with these methods. Further, regarding the dimension of decision-making and response, the measurement scales capture experiences with incidents in tunnels and, thus, relate only indirectly to decision-making and responses during incidents. For more details of the measurement scales, see Supplementary Materials, section 1.2.

Measuring decision-making and responses during emergency and training situations is a difficult task faced by researchers and developers of educational programmes within the fire and rescue services. In this regard, further research could consider the development and improvement of an instrument that can be used to measure the observable performance of fire and rescue personnel in real and training situations. Moreover, since Norwegian fire and rescue personnel have limited experience of major incidents in tunnels, in future versions of the

questionnaire, the measurement scales capturing the dimension of decision-making and response should contain continuous indicators. Initially, the questions were formulated as *Have you been involved in …?*, and the variables were estimated with categorical indicators. To provide more variance in the data, the questions should be formulated as *To what degree have you been involved in …?*.

Since the process of learning has been studied indirectly through observing latent variables and the interpretation of a construct may have different meanings across different groups, another key area for future research should concern invariance testing of the learning model across different groups, potentially in a multi-level CFA accounting for potentially different cultures in the various fire departments. Currently, the gender perspective is unequally distributed within the Norwegian fire and rescue services, and the fire department's organizational structure is twofold, consisting of full-time and part-time employees. Future research should therefore test the model for invariance across the personnel's employment positions. This will offer a more solid knowledge base and provide insight into whether the learning mechanisms observed in this study have the same meaning across these groups.

In all, the results suggest that the content of what is being learned, the context in which learning takes place, learners' commitment to learning activities, involvement in decision-making and responses during incidents, as well as reflection, influence fire and rescue personnel's experiences of change, confirmation and/or comprehension. Furthermore, the effects of content, commitment and reflection have the strongest influence on the outcome of learning. While reflection stands out as the strongest predictor, its mediating effect on the outcome of learning is present only for the dimensions of content and of commitment.

Bearing in mind that the dimension of context appears to capture fire and rescue personnel's assessments of the efficacy of didactical methods used in various learning environments and that the dimension of decision-making and response relates indirectly to performances shown during response operations, further empirical testing of the learning model should be conducted, with potentially further revisions of the items, in order to capture the specific qualities of the context in which learning experiences occur. However, the data demonstrated a good fit of the model, and the latent constructs captured through the questionnaire may provide additional dimensions to the model of learning in emergency response settings, e.g., the efficacy of specific teaching and instruction techniques. Thus, a possible interpretation of this study's findings may point to the possibility of expanding the model to include potential new dimensions. In this sense, besides making a theoretical contribution, our findings may contribute to generating important knowledge of aspects that should be considered if learning is to lead to changes and improvements in performances and working methods, confirmation of current knowledge and practices and/or provide a deeper understanding of practices and behaviours within the fire and rescue services.

In order to secure deep and meaningful learning, educators and practitioners within the fire and rescue services should ensure that all mechanisms depicted in (2013) experiential learning model are present during learning situations. The structural model suggests that the content of learning and learners' commitment to learning activities shape fire and rescue personnel's experiences of change, confirmation and/or comprehension through the effect of reflection. Reflection itself takes a leading position and stands out as a powerful mechanism for learning to occur. Consequently, reflective activities should be emphasized and incorporated explicitly into learning activities.

References

Aase, K. and Njå, O. (2004), "Organizational learning in professional versus non-professional emergency organizations", *11th Annual International Emergency Management Society (TIEMS) 2004 Conference*, Melbourne.

Argyris, C. and Schön, D. (1996), *Organizational learning II: Theory, method and practice*, Reading, MA: Addison-Wesley.

Billett, S. (2001), "Knowing in practice: Re-conceptualising vocational expertise", *Learning and Instruction*, Vol. 11 No. 6, pp. 431-452, doi: 10.1016/S0959-4752(00)00040-2.

Billett, S. (2004), "Learning through work: Workplace participatory practices", in Rainbird, H., Fuller, A. and A. Munro (Eds.), *Workplace learning in context*, London: Routledge, pp.125-141.

Bjørnsen, G. and Njå, O. (2019), " Applying Systems Theory to Increase Competence in Tunnel Fire Safety – Focusing on the Fire and Rescue Services", *Proceedings of the ESREL 29th European Safety and Reliability Conference*, Hannover.

Bjørnsen, G., Njå, O. and Braut, G.S. (2020), "A tool to assess learning processes based on the cooperation principle", in *Engineering assets and public infrastructures in the age of digitalization*, Springer, pp. 87-95.

Bollen, K.A. and Long, J.S. (1993), *Testing structural equation models* (Vol. 154), Sage.

Boud, D., Keogh, R. and Walker, D. (1996), "Promoting reflection in learning: A model", *Boundaries of Adult Learning*, Vol. 1, pp. 32-56.

Brauner, C., Dietz, W., Stampfli, W., Meister, W., Kummer, U., Mundwiler, H., Mariéthod, B., Senggen, E., Luginbühl, P., Wernli, M., Borner, M. and Fink, T. (2016), *Firefighting operations in road tunnels. Tactics-techniques-background*, International Fire Academy.

Braut, G.S. and Njå, O. (2009), "Learning from accidents (incidents)–theoretical perspectives on investigation reports as educational tools", in *Reliability, risk, and safety, three volume set*, CRC Press, pp. 43-50.

Brookfield, S. (1998), "Critically reflective practice", *Journal of Continuing Education in the Health Professions*, Vol. 18 No. 4, pp. 197-205, doi: 10.1002/chp.1340180402.

Browne, M.W. and Cudeck, R. (1992), "Alternative ways of assessing model fit", *Sociological Methods & Research*, Vol. 21 No. 2, pp. 230-258, doi: 10.1177/0049124192021002005.

Dekker, S.W.A., Jonsén, M., Bergström, J. and Herrington, A. (2008), "Learing from failures in emergency response: two empirical studies", *Journal of Emergency Management*, Vol. 6 No. 5, pp. 64-70.

Ellström, P.-E. (2001), "Integrating learning and work: problems and prospects", *Human Resource Development Quarterly*, Vol. 12 No. 4, pp. 421-435, doi: 10.1002/hrdq.1006.

Eraut, M. (2000), "Non-formal learning, implicit learning and tacit knowledge", in Coffield, F. (Eds.), *The necessity of informal learning*, Bristol, UK: Policy Press, pp. 12-32.

Hager, P. (2011), "Theories of workplace learning", in Malloch, M., Cairns, L., Evans, K. and O'Connor, B.N. (Eds.), *The SAGE handbook of workplace learning*, London: SAGE Publications, pp. 17-31.

Hohr, H. (2013), "The concept of experience by John Dewey revisited: Conceiving, feeling and "enliving"", *Studies in Philosophy and Education*, Vol. 32 No. 1, pp. 25-38.

Illeris, K. (2004), "A model for learning in working life", *Journal of Workplace Learning*, Vol. 16 No. 8, pp. 431-441, doi: 10.1108/13665620410566405.

Illeris, K. (2011), "Workplaces and learning", in Malloch, M., Cairns, L., Evans, K. and O'Connor, B.N. (Eds.), *The SAGE handbook of workplace learning*, Sage, London, pp. 32-45.

Kelloway, E.K. (2014), *Using Mplus for structural equation modeling: A researcher's guide*, Sage Publications.

Klein, G. (2015), "A naturalistic decision making perspective on studying intuitive decision making", *Journal of Applied Research in Memory and Cognition*, Vol. 4, pp. 164-168, doi: 10.1016/j.jarmac.2015.07.001.
Kolb, D.A. (1984), *Experience as the source of learning and development*, NJ: Prentice Hall.
Lave, J. and Wenger, E. (1991), *Situated learning: legitimate peripheral participation*, Cambridge University Press.
Levy, R. (1966), "The role of content in learning", *Journal of Thought*, Vol. 1 No. 4, pp. 20-24.
MacKinnon, D.P., Fairchild, A.J. and Fritz, M.S. (2007), "Mediation analysis", *Annual Review of Psychology*, Vol. 58, pp. 593-614.
Malcom, J., Hodkinson, P. and Colley, H. (2003), "The interrelationships between informal and formal learning", *Journal of Workplace Learning,* Vol. 15, pp. 313-318, doi: 10.1108/13665620310504783.
Muthén, B.O. and Muthén, L. (1998-2017), *Mplus user's guide: eighth edition*, CA: Muthén & Muthén.
Muthén, B.O. (1993), "Goodness of fit with categorical and other nonnormal variables", *SAGE Focus Editions*, Vol. 154, pp. 205-234.
Njå, O. and Braut, G.S. (2010), "Components of a Tool to Address Learning from Accident Investigation in the Offshore Industry", *Proceedings of the ASME 2010 29th International Conference on Ocean, Offshore and Arctic Engineering*, Shanghai, China, doi: 10.1115/OMAE2010-20610.
Pintrich, P.R. (2000), "Educational psychology at the millennium: A look back and a look forward", *Educational Psychologist*, Vol. 35 No. 4, pp. 221-226, doi: 10.1207/S15326985EP3504_01.
Preacher, K.J. and Hayes, A.F. (2008), "Asymptotic and resampling strategies for assessing and comparing indirect effects in multiple mediator models", *Behavior Research Methods*, Vol. 40 No. 3, pp. 879-891.
Rake, E.L. (2008), *Crisis management: coping and decision making on-scene*, Doctoral thesis, University of Stavanger, Stavanger.
Rhemtulla, M., Brosseau-Liard, P.É. and Savalei, V. (2012), "When can categorical variables be treated as continuous? A comparison of robust continuous and categorical SEM estimation methods under suboptimal conditions", *Psychological Methods*, Vol. 17 No. 3, pp. 354-373.
Roberts, J.W. (2012), *Beyond learning by doing: Theoretical currents in experiential education*, Routledge.
Schön, D.A. (1991), *The reflective practitioner: how professionals think in action*, Aldershot: Avebury.
Seaman, J. (2008), "Experience, reflect, critique: The end of the "learning cycles" era.", *Journal of Experiential Education*, Vol. 31 No. 1, pp. 3-18, doi: 10.1177/105382590803100103.
Seaman, J., Brown, M. and Quay, J. (2017), "The evolution of experiential learning theory: Tracing lines of research in the JEE", *Journal of Experiential Education*, Vol. 40 No. 4, NP1-NP21, doi: 10.1177/1053825916689268.
Sfard, A. (1998), "On two metaphors for learning and the dangers of choosing just one", *Educational Researcher*, Vol. 27 No. 2, pp. 4-13, doi: 10.3102/0013189X027002004.
Skinner, E., Furrer, C., Marchand, G. and Kindermann, T. (2008), "Engagement and disaffection in the classroom: Part of a larger motivational dynamic?", *Journal of Educational Psychology*, Vol. 100 No. 4, pp. 765-781, doi: 10.1037/a0012840.
Slotte, V., Tynjälä, P. and Hytönen, T. (2004), "How do HRD practitioners describe learning at work?", *Human Research Development International*, Vol. 7, pp. 481-499, doi: 10.1080/1367886042000245978.

Sommer, M., Braut, G.S. and Njå, O. (2013), "A model for learning in emergency response work", *International Journal of Emergency Management*, Vol. 9 No. 2, pp. 151-169.

Sommer, M. and Njå, O. (2011), "Learning amongst Norwegian fire-fighters", *Journal of Workplace Learning*, *Vol.* 23 No. 7, pp. 435-455, doi: 10.1108/13665621111162963.

Tabachnick, B.G., Fidell, L.S. and Ullman, J.B. (2007), *Using multivariate statistics* (Vol. 5), Boston, MA: Pearson.

Vik, H., Berg, O.H. and Lilleeng, B. (Eds.) (2014)*, Handbook for exercise planning [Håndbok i øvelsesplanlegging,* Stavanger, Øvingsutvalget.

Voeltzel, A. and Dix, A. (2004), "A comparative analysis of the Mont Blanc, Tauern and Gotthard tunnel fires", *Routes/Roads*, pp. 18-36.

Wenger, E. (2009), "A social theory of learning", in *Contemporary theories of learning*, Routledge, pp. 217-240.