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Text mining analysis on research trends in workplace safety engagement education

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Abstract: The importance of workplace safety education is being emphasized as a method to minimize damage caused by industrial accidents. This study identified research trends and major components of workplace safety education to establish an academic basis for providing education that enables organizational members to engage in safety at work. A literature search was performed by setting search terms based on education-related words, such as workplace safety education, safety engagement, workplace learning, and vocational training. Eighty articles were selected through the systematic literature review method, and the selected articles were used as unstructured data for research. The R program (version 3.6.3) was used to perform text mining. As a result of the analysis, the topics related to workplace safety education comprised four factors: education component, organizational risk management, workplace environment, and safety competency. This study explored the main themes necessary for workplace safety education model development and derived sub-components. In addition, this study identifies the educational content, methods, and programs to be introduced in Korea and seeks academic and practical directions for future research.

Subjects: Work-based Learning; Educational Research; Research Methods in Education

Keywords: workplace safety education; safety engagement; workplace safety; workplace learning; vocational training; job training; text mining

1. Introduction

1.1. Background of study

Industrial accidents are a serious social problem that negatively affects businesses and society by causing damage to human life and property (Loomis et al., 1997; O'brien et al., 2018). To reduce accidents and keep companies and people safe, it is essential to improve safety awareness and teach safety compliance to workers (Dembe, 2001; Hofmann et al., 2003; Seo et al., 2021). Previous studies have reported that most industrial accidents are caused by human errors, such as mistakes, negligence, and a lack of safety awareness (Dembe, 2001; Griffin & Neal, 2000; Hofmann et al., 2003; Michael et al., 2005; Zohar, 2010). Therefore, various studies have been conducted in academic and industrial fields to raise employees' safety awareness, reduce industrial accidents, and establish a safe workplace environment.

The workplace, including industrial sites, is not merely a workspace but also a living space for people. When the time employees spend at work is meaningful and positive, individuals voluntarily

engage themselves in their work and contribute to the improvement of organizational performance (Maslen, 2014; Ripamonti & Scaratti, 2015; Seo & Hong, 2022). In previous studies related to workplace learning, various topics have been addressed, such as workplace learning, formation, commitment, participation, and innovation, but studies on learning about safety in the workplace remain scarce (Gao et al., 2019; Maslen, 2014; Nam Kung, 2017; Park & Kang, 2017). Safety can be defined as a situation where no human or material loss occurs, even in the case of an accident, and safety is paramount in daily life, including in work environments.

Workplace safety education impacts workers' safety engagement and positively affects the awareness of workers, managers, and management alike. According to previous studies, workplace safety education plays a role in improving the maturity of workplace safety engagement by inducing workers to engage in safety behaviors, establishing and modifying the organization's safety management system, and forming a safety culture or climate (Gao et al., 2019; Mavrikios et al., 2013; Seo et al., 2021; Seo & Hong, 2022). However, research related to workplace safety education remains limited because no specific educational model or major components have been established as effective pedagogy.

1.2. Problem statement

Previous workplace safety education has been conducted practically by reflecting field characteristics as part of the education suitable for each work context as members exchange work-related information with each other at specific sites (Kim et al., 2020; Somerville & Lloyd, 2007; Stemn et al., 2018). The most significant difference from studies in other educational fields is that workplace safety education has no theoretical basis, unlike adult learning or general education. Workplace safety education started with insurance companies raising that the frequency of accidents occurring in an industry depends on the characteristics of the industry at industrial sites and the degree of unsafe employee behaviours, which is seen to be the main cause of accidents. As insurance companies investigated the main causes of safety accidents at industrial sites, the field of safety education took shape within the field of industrial safety engineering by identifying an absence of safety-related content in job training. Accordingly, it is necessary to conduct research on safety education from the perspective of convergence research in the field of education.

In practical terms, workplace safety education is divided according to general workers, managers, and management, although this is problematic because there is no significant difference in content. In particular, learners' roles in the organization have not been clearly understood. This is due to a lack of understanding of work environments, occupations, and experiences. To solve these problems, it is necessary to establish an academic framework for research related to workplace safety education and to analyze its major constituent factors.

Because workplace safety education supports the development of human safety competency through practical training as an essential factor in the process of workplace education, we determined the necessity for a pedagogical model concerning workplace safety education that has until now only been studied sporadically in the fields of safety engineering, business administration, and education. Moreover, workplace safety is a concept that should be embodied in employees.

1.3. Research objective

In this study, the main themes required to develop a model of workplace safety education were explored, and the sub-components were derived. The subcomponents of workplace safety education derived from a literature search were used as basic data for developing a workplace safety education model. In addition, by identifying research trends related to workplace safety education, the contents, methods, and education programs suitable for the Korean context were identified, and academic and practical directions for future research were sought.

We used text mining of academic research on workplace safety education to collect data for this study. Text mining has attracted attention as a research method. It is used in various techniques, such as statistics, networks, frequency, and visualization analysis, to assess large amounts of text data. In this study, text mining was performed using academic literature as text data (Seo & Hong, 2022; Xu et al., 2021). Specifically, text frequency analysis and keyword network analysis were performed to derive keywords and interpret research trends. By applying text mining analysis, data were analyzed to identify research trends, and the content of the education and the main themes were examined. In addition, we suggest educational content, methods, and programs that organizations should introduce to improve workplace safety engagement. Finally, we explore the academic and practical directions for follow-up research.

2. Theoretical background

2.1. Safety competency in the workplace

Safety competency is a concept that includes safety awareness, safety attitudes, and safety compliance. Safety competency means that people can perform appropriate safety behaviors at work based on their knowledge, attitudes, and perceptions necessary to ensure safety in daily life (Han et al., 2009; Lim & Ahn, 2014; Wright et al., 2019). In industrial organizations, safety competency can be defined as the ability of employees to perform work successfully while fully immersing themselves in safety in the workplace environment. Safety competency in the industrial site plays an important function at both the organizational and individual levels. The improvement of safety capability protects members from various damages and threats caused by accidents and maintains continuous organizational functioning (Ripamonti & Scaratti, 2015). At the organizational level, a safe organizational climate ensures continuity of work. Therefore, it is necessary to discuss in detail safety education programs that teach safety competency with an understanding of the specific field, such as workplace risk factors and safety factors.

Safety competency in the workplace can be divided into the individual psychological dimension and the organizational structural dimension. Safety competency at the individual level refers to the ability to comply with organizational safety management regulations based on safety awareness and safety attitudes and to perform individual tasks safely. For a job to be safely performed, it is necessary to understand an individual's attitude about the job and to be able to sustain safety behaviour (Laurent et al., 2018). Research has suggested that employees' safety behaviours are related to their job commitment and motivation and that employees are likely to behave insecurely if they feel unsafe. Processes for cognition, motivation, and responsibility, along with psychological processes, affect an employee's sense of safety (Bakker & Demerouti, 2007; Zohar, 2000).

Safety competency at the organizational level is the ability to protect the organization from risks from inside and outside the organization (Ripamonti & Scaratti, 2015). The organization must provide a safe work environment for its members and ensure work continuity, even in the event of an accident. Safety competency required in the workplace consists of a series of efforts to establish systems, tasks, regulations, and guidelines related to the organization's safety and health management, to actively implement this content in organizational management, and to lower the level of accidents (Kaldenberg et al., 1995; Michael et al., 2005). Safety competency induces employees to behave safely at work and ultimately plays a role in workplace engagement.

2.2. Workplace safety competency and safety education

There are differences in what should be included in training based on the target audience (i.e., organizational role) within an organization (Park & Kang, 2017). Management training should strengthen leadership, including safety leadership and crisis management, to effectively respond to crises inside and outside the organization and motivate members (Al Thani & Obeidat, 2020; Clarke, 2013; Seo & Hong, 2020). Site workers must comply with safety rules and perform work processes in compliance with safety guidelines. In addition, safety managers are obliged to provide

guidance and advice to the workplace regarding how to investigate the cause and prevent recurrence in the event of a disaster (Yang & Park, 2013). Before implementing safety education in the workplace, it is necessary to understand the difference between each subject's roles and responsibilities to target their safety education appropriately. Systematic learning results can be expected when a safety education program reflects the job characteristics or positions of the learners.

In a practical context, safety education can be explained by two theoretical concepts: "engagement" and "embodied cognition." In safety education, experiences based on the learner's engagement and activeness are emphasized, and the learning effects can be improved when experiential engagement-oriented education is conducted (Gao et al., 2019; Goldenhar et al., 2001; Son, 2014). In immersion theory, the learning outcomes derived from the learner's experience are divided into cognitive, emotional, and behavioural dimensions (Christian & Slaughter, 2007; O'brien et al., 2018). Recent studies related to safety education in industrial organizations have been actively researching the field of research on the development of experiential safety education programs based on virtual reality (VR) technology. (Flavián et al., 2019; Meyer et al., 2019). Virtual reality technology provides an environment that utilizes entirely virtual content through immersive equipment and can build an engaging educational environment. In these studies, an experiential education program was designed so that field workers could learn to predict risk factors in the field. This safety education program attempts to increase the applicability and effectiveness in the field based on immersion theory.

Embodied cognition emphasizes interactions with the external environment to understand human cognitive activity (Barling et al., 2002). Embodied cognitive theory and embodied learning challenge the existing view that does not consider the effects of the environment on cognition. Thus, cognitive action emerges through experience, such as the learner's interaction with a given contextual learning environment. According to embodied learning, safety education programs can improve safety competency by allowing learners to recognize and directly perform safety behaviors by interacting with the learning environment.

3. Materials and methods

Text mining (a big-data analysis technique) was performed in this study. Specifically, the literature search was performed after setting a search term, and literature suitable for the research topic was selected. The selected articles were converted into unstructured texts and analyzed through the R program (Version 3.6.3). Accordingly, word frequency analysis and topic modeling were performed to identify research trends in workplace safety education, major research topics, and sub-components. In addition, network analysis was performed based on topics derived through topic modeling. The detailed research procedure is as follows.

3.1. Materials

In this study, academic literature was investigated for text data construction. To limit the scope of the literature to "workplace safety education," "workplace learning," "safety," and "occupational" were selected as essential search terms. Online databases were used to conduct searches, including the Korean Studies Information Service System (KISS), National Digital Science Leaders (NDSL), Science Direct, Social Sciences Citation Index, Google Scholar, Web of Science, Directory of Open Access Journals, Scopus, Springer, and SAGE. A literature search was performed using the detailed article search function.

The search language was set to English, and "-hospital, -nurse, -nursing, -patient, -clinical, -medical, -child" were selected as exclusion words to exclude areas other than occupational safety when searching the literature. Specifically, the literature search was conducted in two stages. The primary literature search took place from January 19 to 2 February 2022 (14 days). The secondary literature search was carried out for a total of 14 days from February 3 to 16 February 2022, and during this period, additional literature searches and a final literature

derivation were performed. The searched articles were classified according to systematic literature review guidelines (Moher et al., 2009) presented by the Preferred Reporting Items for Systematic Reviews and Meta-Analysis (PRISMA) group. To derive the final articles to be used as text data, literature was selected by applying the PICO process. The PICO process is a select method of articles used in evidence-based practice to frame and develop literature search strategies, for instance, in systematic reviews (Luijendijk, 2021; Richardson et al., 1995). The PICO process is a literature review method that is divided into four stages: "Participation", "Interaction", "Comparison", and "Outcomes" and proceeds in sequence. This research method is widely used in literature reviews and qualitative meta-analyses as a way to construct a search strategy suitable for research purposes.

Figure 1 presents the PRISMA flow chart for the selection of research literature. A total of 516 articles were searched for the first step. 297 articles related to exclusion words such as hospital, nursing, and medical care were deleted. 48 articles that did not have original texts or were duplicated were deleted. In addition, 44 documents that did not undergo peer review, such as academic conference proceedings, were also deleted.

In the selection step, the PICO process was applied. The PICO process was carried out through a total of four steps. In the "Participation" stage, literature with topics related to education, such as employee education, organizational learning, job training, and workplace learning, was selected. In the "Intervention" stage, literature was selected on topics related to engagement, such as participation, leadership, attitude, and commitment. The "Comparison" stage was not set because there was no control group. In the "Outcomes" stage, research literature presenting workplace safety education results was selected. What is included in "Outcomes" means the result when members are engaged in safety, such as safety engagement, safety compliance, safety behaviour, and safety commitment. Table 1 presented the PICO process in details.

Through screening, 127 articles were selected, and a total of 76 research papers were selected after excluding papers that did not fit the research topic. In the Eligibility step, 76 previously selected literature on safety engagement, participation, commitment, and behaviour were analysed along with a database search to prevent the loss of essential data required for analysis. In order to secure essential data for analysis, 4 papers were added, and a total of 80 articles were constructed as analysis data.

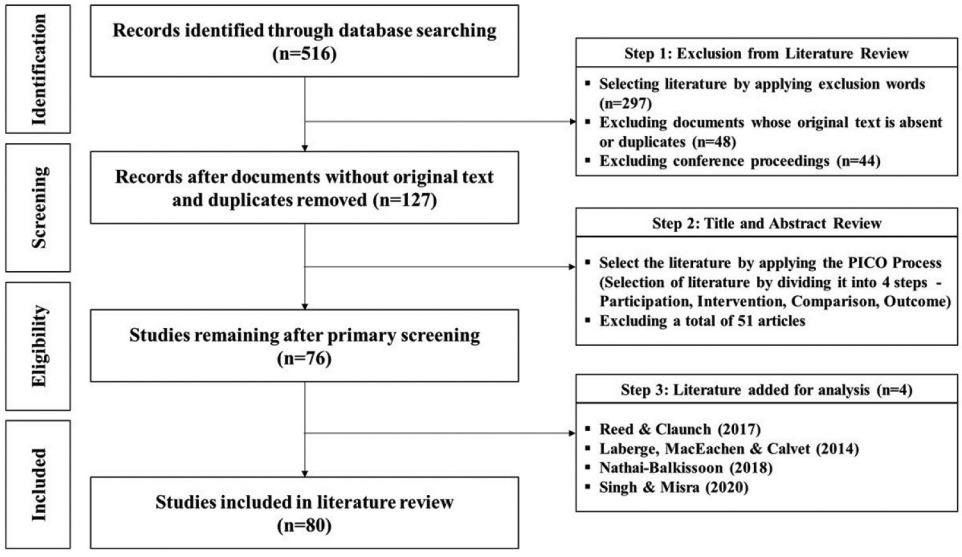

Figure 1. PRISMA flowchart for deriving analytical articles.

Table 1. Presenting the PICO process applied in the screening step

Classification	Details
Participation	employee learning; OR employee training; OR vocational education; OR organizational learning; OR job training; OR workplace learning
AND	
Intervention	participation; OR leadership; OR attitude; OR commitment; OR engagement
AND	
Comparison	no control group
AND	-
Outcome	safety commitment; OR safety compliance; OR safety behavior; OR safety engagement

The literature field was limited to job or employee education, such as employee learning, vocational education, and organizational learning. Participation, engagement, leadership, attitudes, and commitment were suggested as interventions in safety education (or training). In this study, workplace safety education was set as a concept that includes education, learning, and training. This study did not establish a comparison group for workplace safety education. This is because, when conducting a literature search, the details of lectures and practices were not specified in the educational method, and the classification criteria for the education content were not set. Safety engagement, compliance, and behaviours were presented as outcomes of safety education.

Four articles were added to the data for analysis (Laberge et al., 2014; Nathai-Balkissoon, 2018; Reed & Claunch, 2017; Singh et al., 2020). During the initial phase of the literature review, we searched for and selected articles relevant to the subject of this study from the research papers included in the literature. Additional selected research literature was generated as unstructured data and served as a factor in constructing the analysis data. Finally, 80 articles were selected and constructed as text data.

3.2. Methods

In this study, text mining was applied as the data analysis method. The R program (version 3.6.3) was used to analyze and construct data from the selected 80 articles as text data. To examine the keywords of the study regarding workplace safety education, overall keyword frequency analysis, and network analysis were performed. A frequency analysis of keywords extracted from the collected article set was conducted. Keywords with important meanings for each frequency were listed, and topic modeling was performed by calculating the weights of the words. In addition, a centrality analysis between important keywords was performed, and the analysis results were visualized using a word cloud.

For the keyword frequency analysis, texts constructed from the data were first refined according to the purpose of the study. Using the dplyr package and the tm package in R, spaces were removed, as were numbers and special characters. The text forms were unified with lowercase letters, and stop words were removed. Additionally, the terms “based,” “related,” “put,” “give,” “high,” and “paper,” which are unlikely to present the characteristics of the research topic, were added to and removed from the negative dictionary, even if the frequency of occurrence was high. For the visualization of important keywords, the WordCloud package was used. To identify keywords that are influential in research trends related to workplace safety education, a network was constructed with frequently analyzed keywords, and their characteristics were analyzed. The network was visualized using the tidygraph package and the ggraph package by calculating the intrinsic centrality and clustering the texts.

According to previous studies, it is most appropriate to determine the number of topics according to the interpretation derived from the topic, the usefulness of the research content, the scope of analysis, and the judgment of qualified researchers (DiMaggio et al., 2013; McFarland et al., 2013; Seo et al., 2022). Moreover, when setting the number of topics, when the research scope is analyzed in a large category, the number of topics is small, and when exploring subdivisions, the number of topics can be set and extracted. Therefore, this study tried to establish the concept of workplace safety education by examining research trends in workplace safety education conducted to immerse workers in the workplace. We also analyzed the trends and scope of the content.

The analysis was performed by setting four topics: job, work environment, risk management, and safety competency. A text frequency-inverse document frequency (TF-IDF) weighting model was used to evaluate importance, judged by the frequency of word occurrences in the text for each topic. Using this technique, words with high importance were analyzed according to the value of the TF-IDF model by assigning weights and word frequency.

4. Results and discussion

In this study, topic modeling and keyword network analysis were performed for 80 research articles on workplace safety education research. This chapter presents and discusses the general characteristics of literature review data, text frequency analysis results, topic modeling results, and keyword network analysis results.

4.1. Publication trends by year

Figure 2 presents the publication trends for research related to workplace safety education by year. This shows that there are some fluctuations for the 80 analyzed papers, but the number of articles has steadily increased over time.

Workplace safety education is a recognized field of organizational management and job education, and academic discussion has been conducted in earnest since the early 2000s (Griffin & Neal, 2004; Michael et al., 2005). Given the correlation between organizational safety climate and individual safety behavior, it is important to encourage employees' motivation, knowledge, and participation in safety behaviors through safety education (Griffin & Neal, 2004). In another study, productivity, quality, and safety were suggested as the three major goals of an organization's safety management system (Michael et al., 2005). Since these studies were published, research has begun on safety education as an influencing factor in work engagement. Workplace safety education-related research has been conducted on job demands, job resources, organizational commitment, employee engagement, human resources, job characteristics, and workplace environments (Hanvold et al., 2019; Laurent et al., 2014).

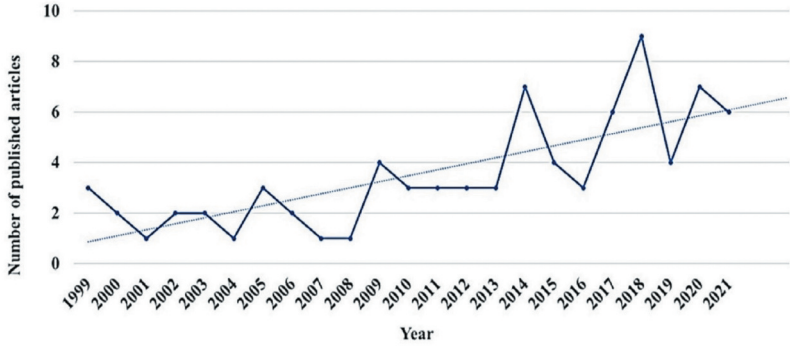

Figure 2. Number of publications in workplace safety education articles by year.

4.2. Text frequency analysis

A total of 3,049 words were used for analysis in this study, and up to 50 keywords related to safety education were identified in order of frequency. The derived workplace safety education research keywords were mostly focused on the practical aspects of education, such as development, analysis, effectiveness, education, research, industry, and workers in educational programs. Excluding the key search terms "workplace learning" and "safety," education, industrial, workers, training, work, study, and disaster were found to have high frequencies (Gherardi & Nicolini, 2000; Lukic et al., 2010; Seok, 2018).

Based on data from these keywords, education for industrial field workers mainly consisted of training for disasters. In workplace safety, trainees mainly work in the construction industry, where the workplace environment is a construction site, so they can be directly affected by natural disasters, such as earthquakes, heavy rain, heavy snowfall, and typhoons. Therefore, the content of workplace safety education should include countermeasures for such natural disasters that occur mainly in the area where the site is located, along with information considering the characteristics of the particular job. When potential disasters are discussed, workplace risks can be identified more clearly, and workers can respond more safely.

It was further found that research on the development of professional manpower training programs has mainly focused on workers and managers, including safety site managers. The importance of individual competency, consciousness, attitude, and motivation was emphasized in safety education for companies. The most common types of research included those that developed professional workforce-nurturing programs and studies analyzing the effectiveness of education and training programs (Ha, 2019; Jeong, 2020; Littlejohn et al., 2014; Maslen, 2014; May et al., 2019; Moher et al., 2009; Son, 2014; Stuart, 2014). Kim et al. (2007) and Ha (2019) applied various analytical models to improve safety education-related effectiveness, efficiency, and effectiveness. Yap and Choy (2018) found that safety education for workers increases efficiency based on integrated interactions, such as the workplace environment, managers, and colleagues.

Safety education program research is primarily conducted in the construction industry, but recently, research has also been conducted in the energy industry, including wind power and offshore industries (Gherardi & Nicolini, 2000; Ha, 2019; Hadikusumo et al., 2017; K. S. Kim & Lee, 2021; Park & Kang, 2017; Sim & Kang, 2017; Yap & Choy, 2018). Research on the development of VR-based safety education, based on immersion theory and transfer theory, has been conducted, and safety behavior induction has been presented as a tangible result (Nykänen et al., 2020; Seo et al., 2021). In particular, the VR-based safety education program has attracted attention as a virtual education method. Table 2 presents the keywords explained above and the frequency and centrality of the words.

Research on recent safety education programs responding to the COVID-19 situation was explored, and various measures have been discussed to continue education, even during a pandemic. Specifically, there have been trends in virtual safety education programs, such as those that use ICT technology or mobile apps or are VR-based. Figure 3 shows a word cloud visualizing the results of text frequency analysis.

4.3. Results of topic modeling

Topic modeling was conducted to understand the research topics most dealt with in workplace safety education-related research, and four topics were derived. Table 3 shows the topic modeling results.

As shown in Table 3, Topic 1 showed the highest rate among the four topics at 32.91%. Topics 2, 3, and 4, were confirmed with 17.89%, 18.85%, and 30.37%, respectively.

Table 2. Keyword frequency analysis and centrality

No.	Word	frequency	Centrality	No.	Word	frequency	Centrality
1	safety	541	0.17884	26	accidents	32	0.01058
2	education	191	0.06314	27	worker	32	0.01058
3	learning	181	0.05983	28	systems	31	0.01025
4	industrial	147	0.04860	29	manager	30	0.00992
5	workers	134	0.04430	30	practices	29	0.00959
6	training	125	0.04132	31	program	29	0.00959
7	work	113	0.03736	32	social	28	0.00926
8	study	96	0.03174	33	organizational	27	0.00893
9	workplace	93	0.03074	34	data	26	0.00860
10	disaster	90	0.02975	35	technology	26	0.00860
11	research	65	0.02149	36	environment	25	0.00826
12	analysis	61	0.02017	37	methods	25	0.00826
13	construction	61	0.02017	38	psychological	25	0.00826
14	effective	60	0.01983	39	development	24	0.00793
15	effect	52	0.01719	40	employees	24	0.00793
16	health	52	0.01719	41	leadership	23	0.00760
17	knowledge	51	0.01686	42	efficacy	22	0.00727
18	industry	44	0.01455	43	small	22	0.00727
19	occupational	42	0.01388	44	actual	21	0.00694
20	risk	42	0.01388	45	lack	21	0.00694
21	factors	40	0.01322	46	accident	20	0.00661

(*Continued*)

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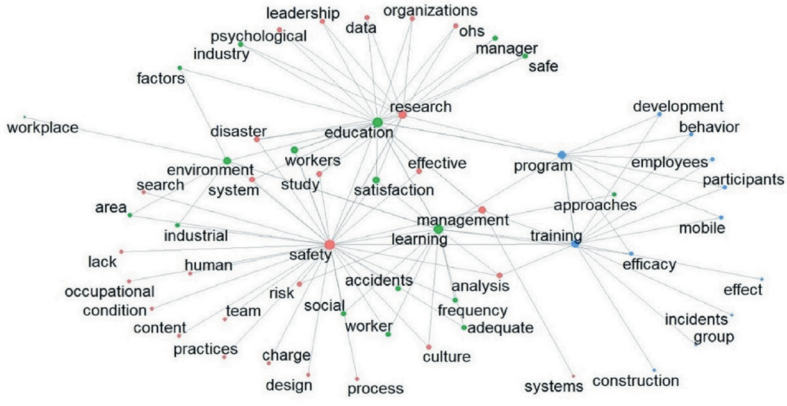
Table 2. (*Continued*)

No.	Word	frequency	Centrality	No.	Word	frequency	Centrality
22	incidents	39	0.01289	47	condition	20	0.00661
23	culture	37	0.01223	48	content	20	0.00661
24	management	34	0.01124	49	group	19	0.00628
25	behavior	33	0.01091	50	transfer	18	0.00595

Figure 3. Text-frequency word cloud analysis results.

Figure 4. Visualization of keyword network analysis results.



Topic 1 was about "workplace safety education factors" and consisted of words such as "learning," "training," "workers," "workplaces," "occupational," "construction," "behavior," and "factors." Workplace safety education of workers in the industrial field consists of behavior- or attitude-based learning and mainly includes technical education-related topics directly applied in the workplace. Adult learning workplace safety education research was being conducted using words such as "higher" and "adult."

In Topic 2, accounting for 17.89%, words such as "organizations," "risks," "behavior," "education," "young," "participants," "management," "culture," "incidents," and "process" were identified as "organizational risk management" content. Risk management not only avoids and eliminates risks but also elucidates the reality of various risks facing industrial organizations and makes optimal decisions about these risks (Barb et al., 2021; Morillas et al., 2013). Ultimately, organizational risk management refers to a set of specific processes that effectively and efficiently carry out the mission and purpose of the organization. As shown in Topic 2, studies were mainly conducted on participation, behavior, education, process, risk management models, and member roles related to organizational risk management.

Table 3. Results of topic modeling

Topic	Keywords	Percentage (%)
1	learning, training, workers, workplaces, occupational, construction, behavior, factors, young, interventions, technical, higher, efficacy, attitudes, experiences, outcomes, performance, case, adult, equipment	32.91
2	organizations, risks, behavior, education, young, participants, management, culture, incidents, process, OHS, model, control, framework, role, prevention, engineers, rules, failure, colleagues	17.88
3	workplaces, organizations, accidents, education, participants, effective, programs, injuries, groups, environment, employees, psychological, vocational, attitudes, feedback, systems, businesses, compliance, job, intention, violations, skills	18.84
4	learning, work, organizations, occupational, health, practices, construction, behavior, knowledge, education, leadership, teams, hazards, human, systems, personal, transformative, falses, PPE, age	30.37

Topic 3 covers the "workplace environment" and consists of words like "workplaces," "organizations," "accidents," "education," "participants," "effective," "programs," and "injuries." In terms of the workplace environment, research was mainly conducted on "organization," "thinking," "education," "participation," and "effective programs." Through words such as "psychological," "feedback," and "compliance," psychological factors in the workplace environment were also identified as important research topics. Other topics being studied include education, continuous feedback, and technical education as countermeasures against accidents and injuries that occur mainly in the workplace.

Topic 4, "safety competency," is composed of words such as "learning," "work," "organizations," "occupational," "health," "practices," "construction," "behavior," "knowledge," "education," and "leadership." In studies related to workplace safety education, competency-related studies have been conducted to determine the competencies that leaders, members, and teams should possess. Topics studied in this category include sick and older workers, as well as personal equipment. Based on the Topic 4 word results, it is possible to infer the safety competencies required in the workplace. Table 4 shows the TF-IDF analysis results by topic modeling. As shown in Table 4, a high frequency of mention of a word does not imply high importance. The TF-IDF value can be determined as the importance of words containing concepts considered important in each topic.

To develop a basic framework for developing a workplace safety education model, we determined that theory can be formed based on embodied cognitive theory and immersion theory when the major components of workplace safety education for industrial workers are identified. Both these theories comprise cognitive, emotional, and behavioral factors, such as workplace safety regulations, work rules, sequence, and industry characteristics. In addition, it was determined that a model framework for workplace safety education could be established based on the factors

Table 4. Word frequency and importance calculation results

NO.	Word	TF	TF-IDF	NO.	Word	TF	TF-IDF
Workplace safety education factors							
1	learning	231	245.94818	11	technical	30	28.44118
2	training	155	103.51355	12	higher	22	27.42371
3	workers	116	44.09709	13	efficacy	22	27.42371
4	workplaces	102	25.77564	14	attitudes	22	27.42371
5	occupational	76	2.90481	15	experiences	20	26.75008
6	construction	59	16.97324	16	outcomes	13	22.65860
7	behavior	52	21.41021	17	performance	12	21.80493
8	factors	41	26.41864	18	case	12	21.80493
9	young	40	26.73818	19	adult	11	20.86832
10	interventions	32	28.33661	20	equipment	8	17.47842
Organizational risk management							
1	organizations	81	2.00010	11	OHS	21	27.11067
2	risks	62	14.81130	12	model	21	27.11067
3	behavior	52	21.41021	13	control	17	25.35813
4	education	41	26.41864	14	framework	14	23.43567
5	young	40	26.73818	15	role	13	22.65860
6	participants	38	27.30167	16	prevention	12	21.80493
7	management	37	27.54430	17	engineers	11	20.86832
8	culture	35	27.94777	18	rules	11	20.86832
9	incidents	32	28.33661	19	failure	10	19.84131
10	process	31	28.40501	20	colleagues	6	14.61670

(*Continued*)

cogent education

Table 4. (*Continued*)

NO.	Word	TF	TF-IDF	NO.	Word	TF	TF-IDF
Workplace environment							
1	workplaces	102	25.77564	11	employees	25	28.09825
2	organizations	81	2.00010	12	psychological	24	27.91562
3	accidents	43	25.70699	13	vocational	23	27.69137
4	education	41	26.41864	14	feedback	17	25.35813
5	participants	38	27.30167	15	systems	16	24.78101
6	effective	33	28.23698	16	compliance	12	21.80493
7	programs	32	28.33661	17	job	11	20.86832
8	injuries	30	28.44118	18	intention	11	20.86832
9	groups	29	28.44405	19	violations	10	19.84131
10	environment	28	28.41246	20	skills	10	19.84131
Safety competency							
1	learning	231	245.94818	11	leadership	23	27.69137
2	work	126	58.23222	12	teams	20	26.75008
3	organizations	81	2.00010	13	hazards	19	26.33959
4	occupational	76	2.90481	14	human	17	25.35813
5	health	76	2.90481	15	systems	16	24.78101
6	practices	61	15.54843	16	personal	12	21.80493
7	construction	59	16.97324	17	transformative	12	21.80493
8	behavior	52	21.41021	18	falses	9	18.71497
9	knowledge	48	23.52990	19	PPE	8	17.47842
10	education	41	26.41864	20	age	6	14.61670

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derived from this study because it corresponds to the "behavioral" factor that enables workers to sustain safety behavior from a practical point of view.

4.4. Keyword network analysis

The network consisted of a total of 58 nodes and 113 edges. The network was constructed by classifying the nodes into three groups with high relevance. The divided topics were "safety," "education," and "program," with words highly related to "safety" in pink, words highly related to "education" in green, and words related to "program" in blue. The node size is larger for words with higher frequencies, and the thickness of the edge does not reflect frequency. The shorter the edge length, the closer the words were to each other. Figure 4 presents data visualized as a network.

Network analysis confirmed that the frequency and relationship between "safety education" and "safety learning" were the highest. Although it is an education field, the relationship between "training" and "program" was the highest. Training is classified as experiential education and is considered to directly affect the induction of safety behavior, safety compliance, and formation of safety attitudes. Both education and learning can be classified as education, but learning was also related to words describing "interaction," such as "environment" and "satisfaction."

5. Discussion

The main themes of workplace safety education comprised the components of workplace safety education, organizational risk management, workplace environment, and safety competency. When the ratio of the four topics was calculated, "Topic 1(workplace safety education)" was 32.91%, "Topic 2(organizational risk management)" was 17.89%, "Topic 3(workplace environment)" was 18.84%, and "Topic 4(safety competency)" was 30.37%, respectively. As a result of classifying the topics, it was confirmed that the importance of safety competency is being emphasized along with safety education in the workplace. Because it is difficult to estimate the importance only with the high frequency of words, TF-IDF analysis was performed, and the results reflecting the importance demonstrated the same trend.

There were various components related to workplace safety education. These components could be classified based on cognition, emotion, and behaviour when interpreted from a pedagogical point of view (Chmiel et al., 2017; Lecours & Therriault, 2018; O'connor et al., 2014; Somerville & Lloyd, 2006). Safety competency comprised various factors, such as training, behaviour, knowledge, education, and leadership, and we analyzed these factors as necessary for competency development. The network analysis results confirmed that the connection between safety, education, program, and learning was the strongest. The concept emphasized in topic modeling and network analysis was "interaction," which was identified as a concept including interactions between individuals and between the workplace environment and individual members. Interdisciplinary research on workplace safety education has been conducted in the lifelong learning and engineering fields.

Work regulations have included safety education in training new workers or re-educating workers. Team learning among workers has been emphasized, and the process of sharing experiences has been conceptualized as learning (Edmondson, 1999; Ennis, 2014; Haunschild & Sullivan, 2002; Yang et al., 2013). In these studies, team learning was defined as a process in which a senior worker becomes a mentor and leads a new worker, and the new worker experientially engages in the process. These studies interpreted safety broadly, including the safety of the work environment, the physical and psychological safety of workers, and the safety in relationships with managers.

As the meaning of the workplace has expanded from merely a workspace to a daily living space, interdisciplinary studies have been conducted in education, psychology, business administration, and safety engineering to safely manage the workplace as an everyday living space. Safety

education becomes more effective when various aspects, such as human cognition, emotion, and behaviour, are considered.

Individual and organizational factors, such as managers, workers, environment, psychology, leadership, and environment, were identified in a complex manner. Interactive workplace safety education enhanced learning and ultimately motivated employees to engage in safety. Based on this text mining-based study, research trends and implications related to workplace safety education will be discussed below.

First, studies related to workplace safety education have mainly been conducted on the effects of training-based education rather than lecture-based education. The words that appeared the most in the related research literature were "industrial, workers, training, disaster, research, [and] construction," except for key search terms. In particular, "training" was an influential word in the keyword network analysis. This is because workplace safety education is training based on practicing actual behaviours and experiences, as simple theoretical education is not a useful way to teach workers safety behaviours. However, workplace safety education does not have an academic background. It was the beginning of education to inform the workers of the risk factors in the field at the time. It has become a form of education in the process of sharing experiences about risky situations that occur during the work process. As the existing workplace safety education-related research reflects work characteristics and risks in the field, it developed based on safety in engineering, and the underlying theories were mostly based on risk scenario techniques or accident case analysis (Cooper, 2009; Olson et al., 2009). Recent interdisciplinary studies have been conducted in various fields, such as education, organization, and business administration, to resolve this problem, but further research is needed on research models to develop safety capabilities.

Second, a total of four topics were derived from the topic modeling analysis: Topic 1 (workplace safety education factors), Topic 2 (organizational risk management), Topic 3 (workplace environment), and Topic 4 (safety competencies). Topic 1 keywords identified major elements constituting workplace safety education, such as job training. These words related to technology, equipment, and performance of safety education, and the words suggested field-related factors that should be reflected in workplace safety education. Workplace safety education could be developed based on these theories. In particular, the results suggest that behavior-based education content should be structured around "experiences."

The main keywords constituting Topic 2 are related to organizational risk management, factors necessary for organizational management, the safety management organization model, and the risk management framework. As a result of deriving TF-IDF by calculating the importance, it was determined that it was highly relevant to organizational management, such as culture, participation, behavior, rules, and colleagues. Future research should additionally analyze the relevance of the organizational management development strategy that analyzes characteristics and jobs when performing workplace safety education. Topic 3 is about the workplace environment and encompasses the characteristics of the workplace, employees' psychological characteristics, job characteristics, and organizational systems. Through the TF-IDF calculation result, it was inferred that accidents or injuries occurring in the workplace are reflected in education and that it is important to provide continuous feedback. If individual factors were identified as important concepts and physical environment and conditions were considered important in the workplace, it was judged that the importance of individual members had increased recently.

Topic 4 was about safety competency and consisted of key terms such as behavior, knowledge, leadership, personal protective equipment, and age. The ultimate goal of workplace safety education is to improve the safety competency of all organization members so that they can immerse themselves in safety at work and maintain the organization continuously. By analyzing the terms emphasized in Topic 4, safety competency was conceptualized as the ability to identify risks in the

workplace, such as behavior, training, knowledge, risk factors, and failure, and the ability to analyze protective equipment and systems. Analyzing the frequency of the co-occurrence words using keyword network analysis and performing centrality analysis revealed that links, such as safety—education, safety—learning, and training—program, had high frequency and relevance in the overall study.

6. Conclusion and implications

This study analyzed the research trends in workplace safety education using text mining and other big data analysis techniques. Specifically, research data was analyzed, and text frequency analysis and keyword network analysis were performed on a total of 80 articles related to workplace safety education to examine the main study topics and the characteristics of the knowledge structure. To build basic data for a workplace safety education model, we analyzed the important topics in workplace safety education, the frequency of words constituting each topic, and the keyword network.

6.1. Implication of the research findings

As a result of the correlation analysis, safety, education, and program were primarily divided into three groups, and research on education and training programs was mainly conducted. In addition, the correlation between words related to interactions, such as workers, environment, workplace, psychological, and behavior, was confirmed. These words are also highly related to factors that play a positive role in improving learning immersion according to immersion theory. It is predicted that future research will continue examining the elements of safety education and interaction-related topics necessary to ensure a safe work environment and improve the maturity of safety engagement.

6.2. Limitations of the research

Research on workplace safety education conducted relatively recently suggests a growing interest in maintaining a safe daily life and solving inclusive social problems. This study comprehensively explored research trends, such as the concept, components, and core topics of workplace safety education. The analysis and discussion were conducted to include the spatial and psychological concept of "workplace," which was not included in any previous safety education. Nevertheless, this study has several limitations. First, academic research on workplace safety education has only been actively conducted since the 2000s, meaning the overall amount of research literature was not large. Since the literature used to construct the text data corpus was limited to academic papers, we determined that it would be somewhat difficult to generalize the research trend of workplace safety education. In addition, although this study attempted to secure the objectivity of the research by using text mining, it is difficult to be sure that researcher subjectivity was completely excluded.

Workplace safety education research is a relatively recent concept, and research was conducted first in the field of engineering, not in the field of pedagogy. Therefore, there was also a limitation in that there was a greater ratio of literature in the field of engineering than in the field of education. This study was conducted to prepare basic data for constructing an appropriate theoretical model by interpreting the meaning of workplace safety education from an educational point of view. Based on engagement, the number of topics suitable for cognition, emotion, behavior, and interaction was determined, and the keywords constituting each topic were analyzed to derive topics and sub-factors necessary for the development of a safety education model. However, we additionally feel, it is necessary to strengthen the connection with the education sector.

6.3. Future research

We intend to develop an in-depth understanding of the influence and relationship of key concepts that constitute workplace safety education. To increase the objectivity of effectiveness, causality, and measurement tools, it is expected that additional analyses, such as path analysis and social network analysis, will be performed to expand the discussion. This study performed text mining to

explore the research trend of workplace safety education. Workplace safety education research has been carried out in earnest since the 2000s and research is being conducted to develop employees' safety competency and improve organizations' ability to respond to various crises.

Approaching safety education from the viewpoints of the humanities and sociology helps researchers and trainers better understand human beings as learners. Therefore, in future studies related to workplace safety education, it is necessary to consider variables and measurement tools that can improve and measure actual learning effects in addition to the concepts, factors, variables, and programs that have been studied thus far.

Workplace safety education is based on behaviorism theory and embodies cognitive theory, so it is important to correct individual attitudes and behaviors and continue to perform work safely. In addition, it was possible to identify risk factors in the workplace in advance and to understand how employees can develop safety capabilities in accordance with their particular job characteristics and positions. It was determined that the results of this study can be used as foundational data for research on safety competency development in the workplace to promote safety engagement during workplace engagement. It is also meaningful in that it showed the potential for further academic research through interdisciplinary research and big data analysis.

This study has a limitation in that it has not specifically developed a new theoretical model of workplace safety education. Therefore, through additional research, we intend to develop a theoretical model based on the topics and keywords derived from this study.

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