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Research article

The design of experimental courses in safety culture

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HIGHLIGHTS

- The existing definitions of safety culture can be briefly divided into three categories.
- Ten experimental courses on safety culture are designed based on the study of the safety culture definitions.
- The connections between the 10 safety culture experimental courses form an "apple".
- Experiments begin with the definition chosen by the students themselves, which can produce dynamic results.
- This paper attempts to transform scientific research achievements of safety culture into teaching.

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ABSTRACT

To promote the application of safety culture in experimental courses that educate safety engineering majors and help students understand the concept and meaning of safety culture more deeply, this paper designed 10 experimental courses in safety culture from the perspective of the definition of safety culture using literature co-occurrence analysis and certain review methods. First, according to the literature research and keyword analysis, the definitions of safety culture can currently be divided into three categories: "the embodiment of safety concepts"; "the synthesis of safety concepts and behaviors"; and "the comprehensive theory of safety culture". Then, based on the study of the definitions, 10 experimental courses were designed and the basis was listed. The final results include 10 safety culture experiments and the relationship between them. The purpose, significance, contents and steps of the 10 experiments are designed to help students better understand the meaning of safety culture and try to transform scientific research achievements of safety culture into teaching.

1. Introduction

The safety engineering major is developing rapidly in China. According to statistics on the websites of the China Education Online and the Ministry of Education [1, 2], the first safety engineering major was established in 1957, and by 2020, 164 Chinese universities had established a safety engineering major. This major involves the fields of national security and defense, aviation, chemistry, petroleum, mining, civil engineering, transportation, energy, environment, medicine, information technology, and finance. Many safety engineering professionals have been trained in various fields.

High-quality safety engineering professionals need not only a solid foundation of professional theoretical knowledge but also strong practical and innovative abilities. An experimental course can effectively develop students' practical and innovative abilities. Experimental course teaching is an important part of university safety engineering majors' education [3], which can cultivate students' practical abilities, combine their theoretical knowledge with practical applications, provide students with a better understanding of professional knowledge, and develop their professional skills [4].

However, there is currently no research on experimental courses in safety culture. In terms of experimental course instruction for safety engineering majors, there is no experimental course that applies safety culture as independent content for education in safety engineering. There are only experimental courses that integrate safety culture perspectives and content into other courses, such as the experimental course in safety management science at the China University of Mining and Technology (Beijing) (CUMTB). In addition, students majoring in safety engineering

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in China are different from those in other countries. For example, in terms of student types, a significant portion of U.S. students majoring in safety engineering are adults with years of work experience and other professional education [5]. Undergraduate safety engineering majors in China do not have work experience but rather learn theoretical knowledge directly in school. Students' lack of practical experience means that the application of safety culture in production and the meaning of safety culture cannot be well understood. However, safety culture plays an irreplaceable and important role in accident prevention and is also essential for improving individual safety awareness [6]. Safety culture has been stipulated in relevant standards and documents in China. For example, China's 14th Five-Year Plan emphasizes that the establishment of an emergency culture is one of the main tasks in building the emergency management system [7]. The Guideline of the China Occupational Safety and Health Management System (GB/T 33000-2016) contains provisions for training in and the establishment of an enterprise safety culture [8]. Safety culture content is also gradually taught in theoretical courses for safety engineering majors in universities; for example, Central South University has opened an elective course called "Safety Culture".

Therefore, it is necessary to design experimental course content with a safety culture as an independent subject. An experimental course in safety culture is conducted through practical teaching, which can help students better understand the meaning of safety culture and is also an attempt to transform scientific research achievements of safety culture into teaching.

2. Status of experimental courses in safety culture research

This section uses literature co-occurrence analysis to analyze the current research on experimental courses in safety culture and illustrates a structure of keyword relationships through VOSviewer.

Keyword co-occurrence analysis clusters literature with similar keywords and shows their relationships through a network structure [9]. All databases purchased by CUMTB were selected to obtain a more comprehensive literature. The databases include CNKI (China National Knowledge Infrastructure), Wanfang Data, Chaoxing Database, Chinese Social Science citation database, Web of Science, Engineering Village, and ScienceDirect. Journal papers, dissertations, books, and conference papers in Chinese and English were all included in the search scope.

Given the research's timeliness, this study collects the literature published in 2017–2021. This research used three search terms to explore databases: “safety culture”, “safety engineering”, and “experimental course”. In total, 7906 studies on safety culture and 1073 studies on experimental courses in safety engineering were analyzed. The literature data were imported into VOSviewer to illustrate the structure of the literature co-occurrence analysis.

The co-occurrence map is obtained by co-occurrence analysis to find the structure distribution of the research status and hotspots. In the co-occurrence map, the circle graphic and its label together form an element. The size of an element is determined by the frequency of the node elements, the strength of the line association and the cited amount of literature. The color of an element represents the cluster to which it belongs, and different clusters are represented by different colors.

The results of the co-occurrence analysis are shown in the co-occurrence maps in Figures 1 and 2. In Figure 1, the red clusters are “Experience”, the yellow clusters are “Management”, the blue clusters are “Survey” and “Improvement”, and the green clusters are “Effect”. In Figure 2, the red clusters are “Technology”, the yellow clusters are “Student”, the blue clusters are “Intervention”, and the green clusters are “Education”.

According to Figure 1, the research on safety culture mainly focuses on questionnaire surveys, management, safety culture improvements, safety climates, behaviors, and safety culture's effects [10, 11, 12, 13, 14]. According to Figure 2, experimental course research focuses on student education, training, and experimental course projects, such as case analyses, questionnaires, simulations, and safety training [15, 16, 17]. For the experimental course research on safety culture, only Zhao et al. integrated safety culture perspectives into their research on safety management science and its experimental course and to designed the experimental course content of safety management science [18]. Apart from that study, there is no research on designing experimental courses in safety culture as independent content. Therefore, safety culture needs to be studied in depth as an independent subject in an experimental course. In addition, there are many studies involving the definition of safety culture. However, there is no unified definition of safety culture [19], and various studies have proposed many different types of definitions.

In summary, there are no studies that have designed experimental courses in safety culture as independent content. There are many studies on the definition of safety culture, but there are still no consistent views.

Based on the above, this research on experimental courses in safety culture is designed as follows: based on the definition of safety culture, this paper starts with the experiment related to safety culture definition, studies and lists the basis of the experimental course, then designs the specific content and steps of the experimental course. The study route is shown in Figure 3.

3. Definition of safety culture

This section reviews and classifies existing studies on the definition of safety culture, and the basic characteristics of safety culture are discussed

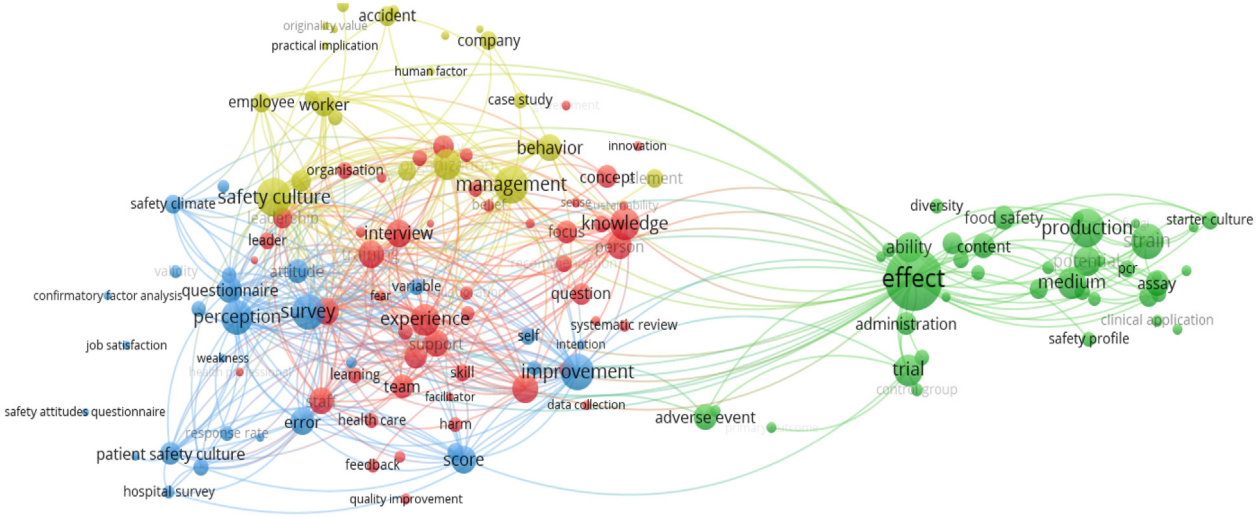

Figure 1. Co-occurrence map of safety culture.

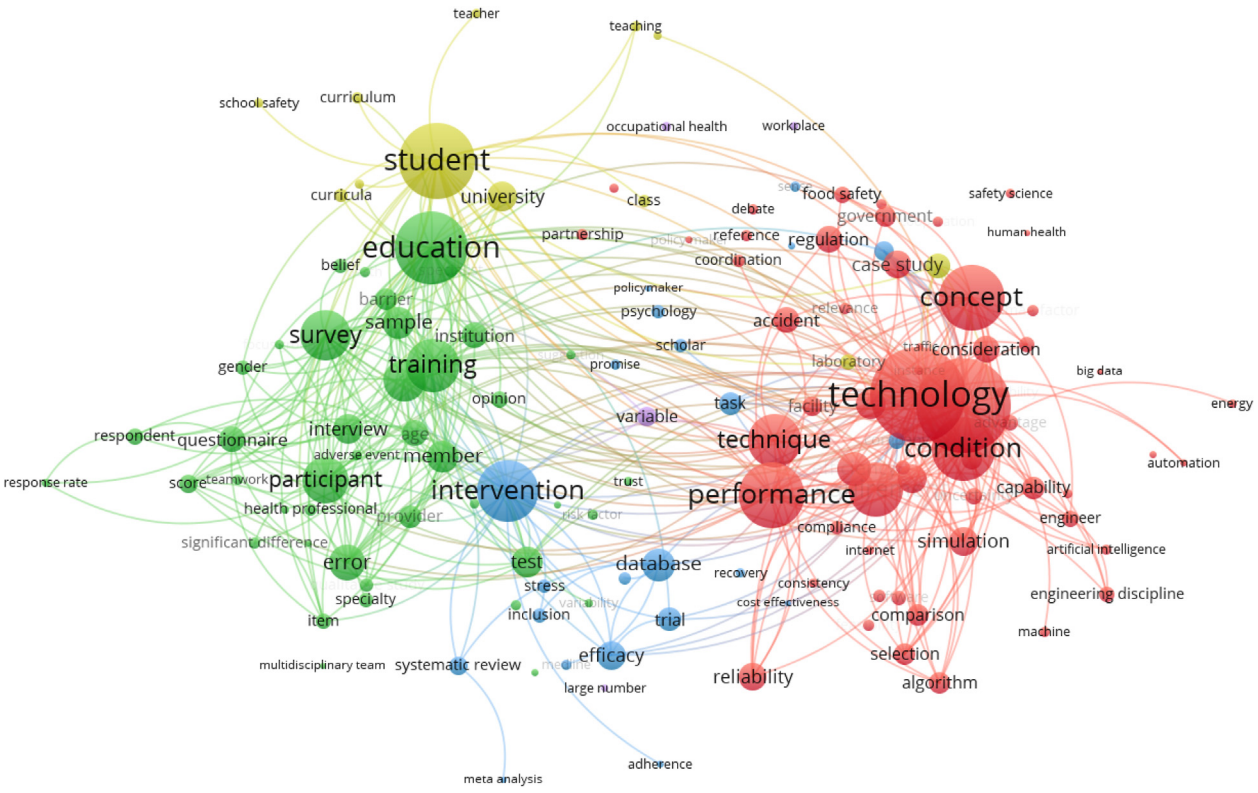

Figure 2. Co-occurrence map of experimental courses.

to classify the definitions. The study and classification of the safety culture definitions provide the basis for the design of the safety culture experimental courses.

3.1. Review of safety culture definition studies

Since the 1990s, safety culture has been widely studied, and one of the first things that received attention was its definition. This paper summarizes the definitions of safety culture proposed by scholars or organizations in various countries based on research since the concept of safety culture was introduced, as shown in Table 1. The definitions listed in Table 1 are only definitions of safety culture and do not include safety climate.

3.2. Safety culture definition classification and analysis

As seen in Table 1, most of the safety culture definitions include attitudes and values, and some of them also include elements such as behavioral styles or material conditions. According to the coverage of safety culture definitions, this paper broadly classifies safety culture definitions into the following categories.

(1) Safety culture is a collection of safety concepts. The definition of this category focuses on attitudes, concepts, values, beliefs, etc., and considers safety culture to be a collection of one or more of the above concept elements.
(2) Safety culture is a collection of safety concepts and behaviors. This type of definition adds the element of behavior and considers safety culture to be the sum of safety behaviors and intangible aspects such as safety values and concepts.
(3) The comprehensive theory of safety culture entails a very broad definition of safety culture that contains not only the elements of safety-related attitudes, values, beliefs, and concepts but also tangible aspects, such as norms, and behaviors. This theory can also be described as the sum of both nonmaterial and material aspects.

What these three types of definitions have in common is that they all recognize the conceptual elements of safety culture. However, different scholars have different opinions regarding whether material conditions, behaviors or norms belong to or are elements of safety culture, and this disparity also informs the current disagreement over the definitions of safety culture.

The safety culture definition is the basis for the experiments designed in this paper, and the basis for the experimental design is described in Section 4.

4. The design of the safety culture experiment and its basis

Ten experimental safety culture courses were designed according to the safety culture definition and its refined elements. The refined elements can be found in reference [68]. Based on the origin and association of each experiment, an "apple" of safety culture experimental courses is formed, as shown in Figure 4.

The relationship between the safety culture definition and other experiments is shown in the "apple" of Figure 4. The "Apple Stem and Leaf" is the basis for the design of all safety culture experimental courses; the "Apple Flesh" shows all the experimental courses and the relationship between each course; and "the Bottom of the Apple" expresses the final purpose of each experiment. The specific design process and basis of each experiment are as follows.

Experiment 1: Mastering the definition of safety culture. In Section 3, the definitions of safety culture are divided into three types. This experiment can guide students to learn the current definitions of safety culture and allow them to summarize and discover the differences between the different definitions of safety culture. This is similar to the process of classifying the definitions of safety culture.

Experiment 2: Mastering safety culture elements. The authors have determined that there are found main ways of extracting safety culture

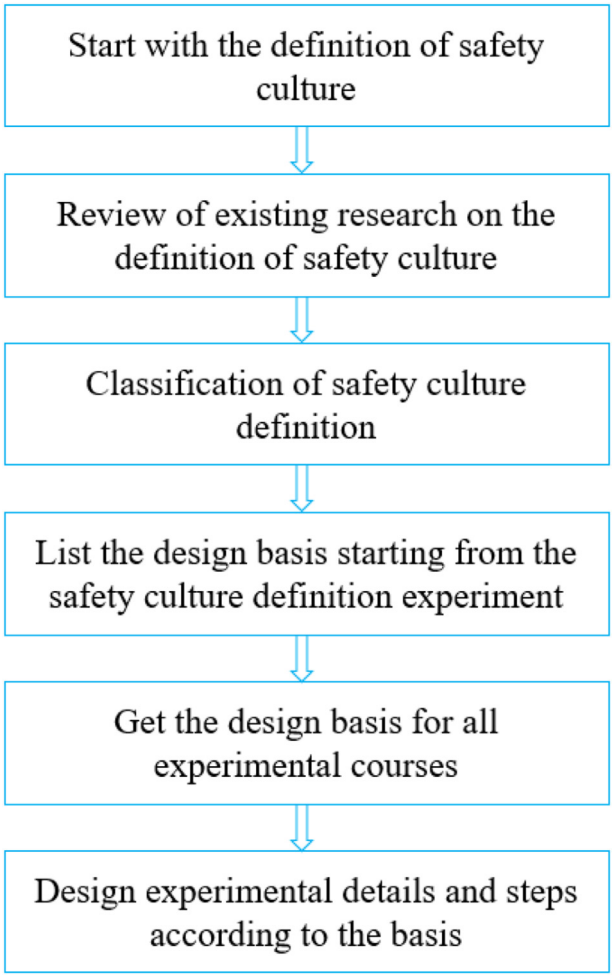

Figure 3. The study route.

elements: (1) improving on the basis of one (or several) researchers; (2) screening elements that appear more frequently through literature reviews; (3) drawing on international, national or industry-related standards; and (4) drawing on other sources, such as differences between companies with high and low accident rates, company characteristics and safety management needs, comparisons between different industries, expert experience, group discussions, etc. [68]. Due to the limited class time, the experimental course designed in this paper uses a method that allows students to select one of the three safety culture definitions and refine the selected definition to obtain safety elements. This way, the safety culture elements obtained will be different for each student. There are two reasons for this:

First, different definitions can obtain different elements. For example, if students choose the first type of safety culture definition in Section 3.2, that safety culture only involves safety concepts, and the corresponding safety culture elements will include only conceptual elements such as attitudes, ideas, values, perceptions, and beliefs. If students choose the second type of definition, behavioral elements, such as behavioral standards and styles will be added in the safety culture elements. The same applies to the third type of safety culture definition.

Second, even the same definition may be refined to different elements. This is due to the differences in students' understanding of the safety culture definition. For example, if students choose the first type of definition to consider safety culture as a safety concept, there are still differences in student understandings of what a safety concept entails and its scope. As a result, there are still differences in the elements of safety culture.

It can be seen from the above analysis that the definition of safety culture in Experiment 1 forms the basis of Experiment 2.

Experiment 3: Safety culture questionnaire design. This experiment is based on the elements of safety culture obtained in Experiment 2. Several questions can be designed for each element, and one question is taken from each element to form a questionnaire. Therefore, the content of the questionnaire is related to the elements obtained in Experiment 2.

Experiment 4**:** Quantitative measurement of safety culture. The safety culture questionnaire used for measurement in Experiment 4 is from Experiment 3. The equipment and facilities used for the measurements and the specific procedures are described in reference [69]. From this experiment students can learn how to use the safety culture questionnaire to reflect the participants' understanding of safety culture. Therefore, Experiment 4 is a quantitative measure of a safety culture based on the safety culture questionnaire designed in Experiment 3.

Experiment 5**:** Analysis of safety culture measurement results. The analysis of safety culture measurement results is the students' further analysis and understanding of the quantitative measurement results in Experiment 4. Experiment 5 enables students to learn to analyze the measurement results from various perspectives. Furthermore, the analysis results can be used as the basis for Experiment 6 and Experiment 7.

The experiment will focus on guiding students to analyze the impact of factors on the results, such as work experience, education, gender, and different personnel (management, front-line employees, etc.), and analyze the underlying reasons based on the results. Students can also design other analytical perspectives by themselves.

Experiment 6: Safety culture training design. Safety culture training is an important tool for the practical application of safety culture in China. The safety culture training designed in this experiment is based on the safety culture definitions and elements in Experiment 1 and Experiment 2 Students can learn to expand on the definition and elements of safety culture and present them in the form of cases and texts. To make the designed safety culture training content more targeted, the analysis of safety culture measurement results in Experiment 5 can be used to understand the problems of respondents in safety culture-related aspects before the design of training content. Therefore, the training can be designed to address the problems. The different definitions chosen by the students will be directly related to the design of the safety culture training contents. The above analysis shows that Experiment 6 is designed on the basis of Experiments 1, 2 and 5.

Experiment 7: Designing safety culture carriers. This experiment is a practical manifestation of safety culture definitions and elements. The design goal of safety culture carriers is to express the internal meaning of safety culture elements in vivid external forms. Therefore, the safety culture definitions and elements involved are reflected in the safety culture carriers. The different definitions chosen by students also determine the design of the corresponding carriers. Furthermore, through the analysis of safety culture measurement results, students can identify the shortcomings of the current safety culture construction, so as to carry out targeted carrier design.

Therefore, Experiment 7 was designed based on Experiment 1, 2, and 5.

Experiment 8: Safety culture evaluation indicators. The quantitative measurement of safety culture in Experiment 4 involves only the level of safety culture in an enterprise. The role and results of a safety culture are not addressed. Safety culture evaluation is a systematic measurement to understand the current situation of enterprise safety culture or the effect of enterprise safety culture construction, which can draw qualitative or quantitative analysis conclusions. In 2007, Shandong, Guangdong, Liaoning, Beijing and other provinces in China took the lead in creating safety culture demonstration enterprises. On January 1, 2009, the "Guidelines for Enterprise Safety Culture Construction" (AQ/T9004-2008) and "Guidelines for Evaluation of Enterprise Safety Culture Construction" (AQ/T9005-2008) came into effect. Subsequently, on January 14, 2010, the "Guideline of the State Administration of Safety Supervision on the Creation Activities of Model Enterprises for Safety Culture Construction" (General Administration of Safety Supervision [2010] No. 5) was issued as

Table 1. Summary of safety culture definition.

No.	Year	Author	Definition of safety culture
1	1983	Uttal, B. [20]	Shared values and beliefs within an organization that influence organizational structure and behavior.
2	1989	Turner, B. A., et al. [21]	The specific set of beliefs, norms, attitudes, roles, and social and technical practices within an organization which is concerned with minimizing, exposure of employees, managers, customers and members of the general public to conditions considered to be dangerous or injurious.
3	1991	International Safety Advisory Group [22]	Assembly of characteristics and attitudes in organizations and individuals which establishes that, as an overriding priority, nuclear plant safety issues receive the attention warranted by their significance.
4	1991	Cox, S., et al. [23]	Safety cultures reflect the attitudes, beliefs, perceptions, and values that employees share in relation to safety.
5	1991	British Industrial Union [24]	The ideas and beliefs that all members of the organisation share about risk, accidents and ill health.
6	1993	Advisory Committee on the Safety of Nuclear Installation (ACSNI) [25]	Safety culture of an organization is the product of individual and group values, attitudes perceptions, competencies, and patterns of behavior that determine the commitment to and the status and proficiency of organization's health and safety management.
7	1993	UK Health and Safety Committee [26]	The safety culture is a unit of individual and collective values, attitudes, skills and behavior of the composite product, it depends on the commitment to health and safety management, work style and proficiency.
8	1993	Ostrom, L., et al. [27]	Organization's beliefs and attitudes, manifested in actions, policies, and procedures, affect its safety performance.
9	1993	Cao, Q. [28]	Safety culture is the sum of safety values (concepts), safety behavior guidelines (norms) and safety behavior qualities (performance). There are positive and negative safety culture, the definition of positive safety culture: the total combination of values of "safety is the first", the code of conduct of "safety is the first" and the behavior quality of "safety is the first". Generally, positive safety culture is referred to as "safety culture". The definition of negative safety culture: the value of neglecting safety, the consistency of violations and the quality of unsafe behavior.
10	1994	Geller, E.S. [29]	In a total safety culture, everyone feels responsible for safety and pursues it on a daily basis.
11	1996	Ciavarelli, A.J., et al. [30]	Safety culture is defined as the shared values, beliefs, assumptions, and norms that may govern organizational decision making, as well as individual and group attitudes about safety.
12	1996	Lee, T.R. [31]	The safety culture of an organisation is the product of individual and group values, attitudes, perceptions, competencies, and patterns of behavior that determine the commitment to, and the style and proficiency of, and organisation's health and safety management.
13	1996	Berends, J.J. [32]	The collective mental programming towards safety of a group of organisation members.
14	1998	Mearns, K., et al. [33]	Safety culture is defined as the attitudes, values, norms, and beliefs that a particular group of people share with respect to risk and safety.
15	1998	Kennedy, R., et al. [34]	Safety culture is a sub-element of the overall organisational culture. It is an abstract concept which is underpinned by the amalgamation of individual and group perceptions, thought processes, feelings and behaviour which in turn gives rise to the particular way of doing things in the organisation.
16	1998	Carroll, J.S., et al. [35]	Safety culture refers to a high value (priority) placed on worker safety and public (nuclear) safety by everyone in every group and at every level of the plant. It also refers to expectations that people will act to preserve and enhance safety, take personal responsibility for safety, and be rewarded consistently with these values.
17	1998	Flin,R., et al. [36]	"Safety culture" refers to the entrenched attitudes and opinions which a group of people share with respect to safety.
18	1998	Helmreich, R.L., et al. [37]	Safety culture: A group of individuals guided in their behavior by their joint belief in the importance of safety, and their shared understanding that every member willingly upholds the group's safety norms and will support other members to that common end.
19	1999	Eiff, G. [38]	A safety culture exists within an organization in which each individual employee, regardless of their position, assumes an active role in error prevention, and that role is supported by the organization.
20	1999	Minerals Council of Australia [39]	Safety culture refers to the formal safety issues in the company dealing with perceptions of management, supervision, management systems, and perceptions of the organization.
21	1999	Clarke, S. [40]	Safety culture is often seen as a subset of organizational culture, where the beliefs and values refer specifically to matters of health and safety.
22	2000	Cooper, M.D. [41]	Safety culture is a subfacet of organizational culture that is thought to affect member's attitudes and behavior in relation to an organization's ongoing health and safety performance.
23	2000	Glendon, A.I., et al. [42]	Safety culture comprises attitudes, behaviours, norms and values, personal responsibilities as well as such HR features as training and development.
24	2000	Hale, A.R. [43]	Safety culture: the attitudes, beliefs and perceptions shared by natural groups, which determine how they act and react in relation to risks and risk control systems.
25	2000	Guldenmund, F.W. [44]	Safety culture is defined as: those aspects of the organisational culture which will impact on attitudes and behaviour related to increasing or decreasing risk.
26	2001	Pidgeon, N. [45]	Safety culture is the set of assumptions, and their associated practices, which permit beliefs about danger and safety to be constructed.
27	2002	Wiegmann,D.A., et al. [46]	Safety culture is the enduring value and priority placed on worker and public safety by everyone in every group at every level of an organization. It refers to the extent to which individuals and groups will commit to personal responsibility for safety, act to preserve, enhance and communicate safety concerns, strive to actively learn, adapt and modify (both individual and organizational) behavior based on lessons learned from mistakes, and be rewarded in a manner consistent with these values.
28	2003	Mohamed, S. [47]	Safety culture is a sub-facet of organizational culture, which affects workers' attitudes and behavior in relation to an organization's on-going safety performance.
29	2003	Ahmad, R.K., et al. [48]	The safety culture of an organization is essentially a description of the attitude of personnel about the company they work for, their perceptions of the magnitude of the risks to which they are exposed and their beliefs in the necessity, practicality and effectiveness of controls.
30	2003	Yu, G.T., et al. [49]	Safety culture is a collection of people's values, attitudes and behaviors regarding safety issues. Safety culture has two main components. One is the framework determined by organizational policies, procedures and management behaviors. The second is the collective responses of individuals and groups, such as values, beliefs, and behaviors.

(*continued on next page*)

Table 1 (*continued*)

No.	Year	Author	Definition of safety culture
31	2004	Richter, A., et al. [50]	Safety culture is the shared and learned meanings, experiences and interpretations of work and safety—expressed partially symbolically—which guide peoples' actions towards risks, accidents and prevention. Safety culture is shaped by people in the structures and social relations within and outside the organization.
32	2004	Reiman, T., et al. [51]	The safety culture is thus considered to be independent of (or only loosely dependent on) the wider organisational culture. This conceptual separation easily reduces the term safety culture to refer only to factors that are known in advance and are clearly connected with safety, such as safety attitudes and safety values.
33	2004	Xu, D.S. [52]	Safety culture is to point to in the process of human development, the production, in all areas of life, survival and scientific practice, to ensure human safety and health of body and mind, and make it safe, comfortable, efficient in all activities, in order to prevent, avoid, control and eliminate accidents and disasters, to build a safe and reliable, harmonious harmless environment and the matching operation of the safety system, To make human health, make the world love, peace and create the sum of material wealth and spiritual wealth.
34	2005	Hopkins, A. [53]	Safety culture is about organisational collective practices. He emphasises that this view is more useful than the concept of culture as values because it provides a practical means of ensuring cultural changes. This understanding of safety culture supports the knowledge that culture is specific to a group because the practices of one group are unlikely to be relevant in their entirety to another.
35	2005	Fang, D.P., et al. [54]	Safety culture refers to the understanding and attitude towards safety, or the patterns and rules for dealing with safety issues.
36	2006	Outline for the Implementation of Safety Culture Building in the11th Five-Year Plan promulgated by the State Administration of Work Safety [55]	Safety culture is a comprehensive reflection of safety production in the field of ideology and people's mindset, including safety values, safety judgment standards and safety capabilities, and safety behavioral approaches.
37	2007	Li, Y. [56]	Safety culture is the understanding and attitude towards safety or the pattern and rules of deviating from safety issues. It is the sum of safety awareness, safety goals, safety responsibilities, safety literacy, safety habits, safety values, safety technology, safety facilities, safety inspections and various safety laws and regulations and rules of an organization or enterprise.
38	2009	Guidelines for the Building of Safety Culture in Enterprises AQ/T9004-2008 [57]	Enterprise safety culture (also referred to as safety culture in this standard) refers to a unified body of safety values, attitudes, ethics and behavioral norms shared by a group of employees in a corporate organization.
39	2009	Assessment Standards of Enterprise Safety Culture developing AQ/T9005-2008 [58]	
40	2009	Fu, G. [59]	Safety culture is the safety concept.
41	2010	Nævestad, T.O. [60]	Shared frames of reference that guide individuals' in workplace settings interpretations of hazards, and that motivate and legitimize preventive practices.
42	2013	Edwards, J.R.D., et al. [61]	Safety culture can be viewed as the assembly of underlying assumptions, beliefs, values and attitudes shared by members of an organization, which interact with an organization's structures and systems and the broader contextual setting to result in those external, readily-visible, practices that influence safety.
43	2014	Gillen, M., et al. [62]	Deeply held but often unspoken safety-related beliefs, attitudes, and values that interact with an organization's systems, practices, people, and leadership to establish norms about how things are done in the organization.
44	2016	Griffin, M.A., et al. [63]	Safety culture typically refers to the underlying assumptions and values that guide behaviour in organisations rather than the direct perceptions of individuals.
45	2017	Petitta, L., et al. [64]	Organizational safety culture provides a more qualitative distinction about the types of ingrained safety-related beliefs, attitudes, and values within the organization.
46	2018	US Nuclear Regulatory Commission（NRC） [65]	The core values and behaviors resulting from a collective commitment by leaders and individuals to emphasize safety over competing goals to ensure the protection of people and the environment.
47	2019	Al-Bayati, A.J., et al. [66]	Safety culture was considered as the core values of a company or business that are indicative of the underlying beliefs and principals that guide safety decision making.
48	2022	Siuta, D., et al. [67]	“Safety culture” is defined as a set of values, conditions, procedures, and behaviors recognized both individually and collectively in the organization under consideration, regarding the organization of a management system to prevent and protect against errors, incidents, breakdowns, cyber-attacks, system integration, and accidents, and to promote safety-oriented behaviors between cooperating organizations in normal and emergency situations.

a guide for the creative activities of model enterprises. The above two standard documents all involve safety culture evaluation. Therefore, Experiment 8 is further designed. The contents of the safety culture evaluation in Experiment 8 are all from the above standard documents.

Safety culture quantitative measurement is a part of safety culture evaluation, so Experiment 4 is the basis of Experiment 8.

Experiment 9: The role of safety culture - accident case studies. According to 24 Model, the root cause of the accidents is safety culture. Safety culture elements can be extracted from cases of accidents, and the frequency of the safety culture elements in the accident cases can be obtained, which is the verification of Experiment 2. Thus, Experiment 9 is designed based on Experiments 1 and 2.

This experiment enables students to appreciate the role of safety culture more deeply and further their understanding of the meaning of safety culture. It is also a validation of Experiment 2.

Experiment 10: The similarities and differences in safety culture in accident cases. This experiment is based on Experiment 9. It enables students to analyze multiple accident cases, and the differences in safety culture in each case can be found. Based on the differences in the actual cases, students can gain a deeper understanding of how safety culture and its elements have an impact on actual safety management. Therefore, Experiment 10 is based on Experiments 1 and 2, as well as Experiment 9.

In addition, Experiments 9 and 10 are also based on the previous 8 experiments. Experiments 9 and 10 guided students to apply their learned theoretical knowledge to discover the causes of a safety culture through actual accident case studies.

Therefore, the above analysis shows that the choice of definition of safety culture is the basis of the whole experimental course design. The students' choice among the different definitions will directly determine the extraction of safety culture elements and the design of the questionnaire,

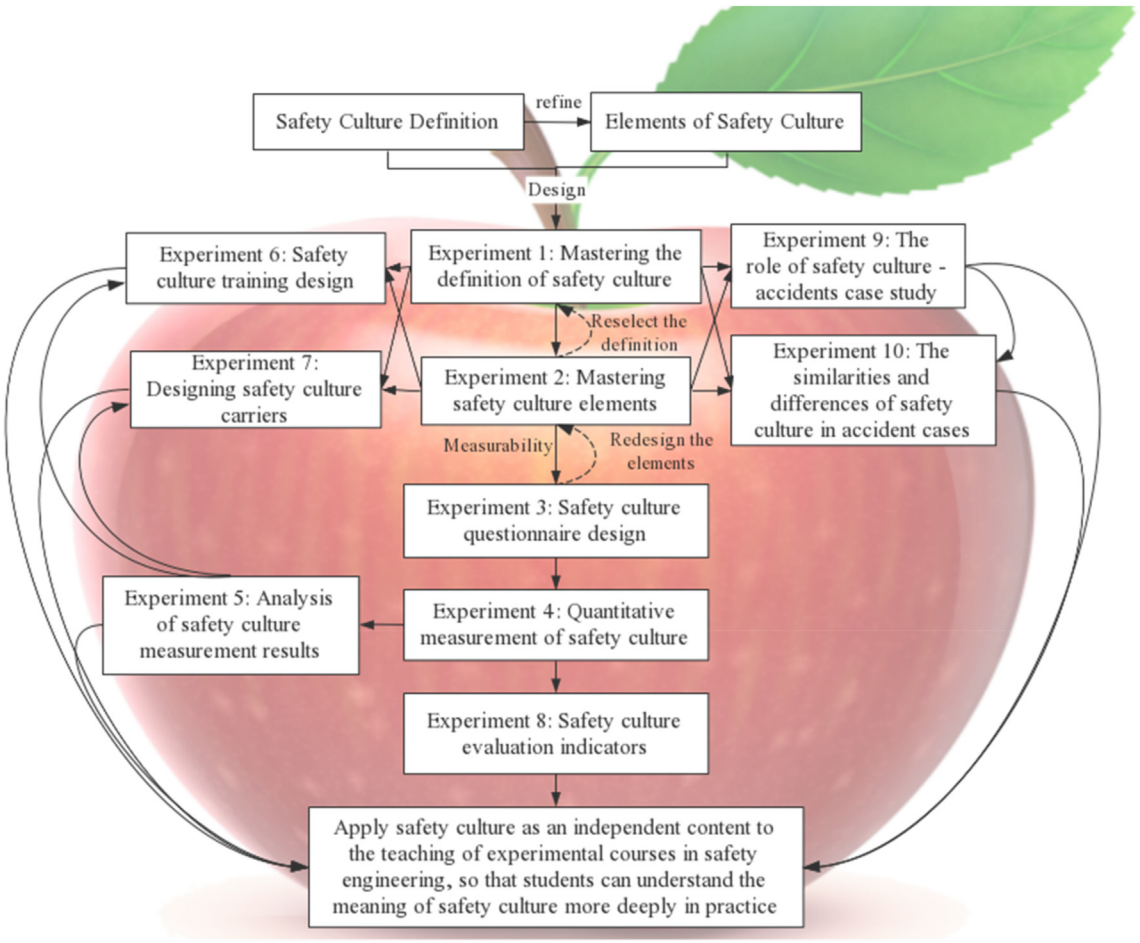

Figure 4. Experimental course in safety culture's "apple".

which will lead to different measurement results. The results of all subsequent experiments change dynamically depending on the choice of the previous definitions.

5. The contents of safety culture experimental courses

This section designs 10 safety culture experimental courses according to the design basis of Section 4. It includes the specific purpose, content, and steps of each experiment.

Experiment 1: Mastering the definition of safety culture

Purpose and Significance: To provide students with a deep understanding of the meaning of safety culture and to provide a design basis for subsequent experiments.

Content Overview: Experiment 1 enables students to understand the definition of safety culture. Based on the three types of safety culture definitions mentioned in Section 3, students choose one that they think is correct and try to explain the reasons for their choice. Since it is the students' own choice, this is theoretically more helpful for students to master the knowledge of safety culture.

Experimental steps

(1) Students learn and summarize the existing definitions of safety culture.
(2) Students understand and master the classification of the safety culture definitions and understand the meaning of different definitions.
(3) Students choose one of the categories of safety culture definition as the basis for their subsequent experiments.

Experiment 2: Mastering safety culture elements

Purpose and Significance: Safety culture elements are the concrete expression of safety culture. Therefore, this experiment can help students understand the meaning of safety culture more deeply and master the meaning and refining process of safety culture elements.

Content Overview: Students independently refine safety culture elements based on the definitions they chose. Due to the differences in the elements that are refined according to the different definitions, each is able to reflect on the safety culture in different aspects. In the experiment, students can return to Experiment 1 to select a different definition and then refine its safety culture elements.

Experimental steps

(1) Students learn and summarize the existing research on safety culture elements, consider the safety culture element source methods and analyze the methods' advantages and disadvantages.
(2) Students refine the safety culture elements into different aspects based on the definitions selected in Experiment 1.
(3) Students analyze how each aspect reflects the meaning of their safety culture definitions.
(4) Students refine their safety culture elements in each aspect, designing each element and explaining their reasons for the design.
(5) If it is difficult for students to refine the safety culture elements during Experiment 2, they can return to Experiment 1 to reselect a different type of definition and then refine the elements.

Experiment 3: Safety culture questionnaire design

Purpose and Significance: Safety culture can be measured by its elements. Students are able to learn the measurability of safety culture elements and master the safety culture questionnaire design.

Content Overview: Students are first required to learn the principles of questionnaire design and choose their questionnaire format. Based on the safety culture elements they designed in Experiment 2, students will design the corresponding safety culture element measurement questions. Each element can design one or more questions and then select one question from each element to form a safety culture questionnaire. If, in the process of questionnaire design, it is difficult to design questions based on the selected elements, or if the elements are found to be unmeasurable, students can return to Experiment 2 to redesign the safety culture elements or return to Experiment 1 to reselect their definition.

Experimental steps

(1) Students learn the principles of questionnaire question design and choose their questionnaire's design form.
(2) Students design corresponding measurement questions according to the safety culture elements designed in Experiment 2. Each element should correspond to one or more questions to design a safety culture questionnaire.
(3) If students find it difficult to design questions based on the elements, or the elements are not measurable, they can return to Experiment 2 and redesign the safety culture elements or return to Experiment 1 and choose a new definition.

Experiment 4: Quantitative measurement of safety culture

Purpose and Significance: To enable students to understand and master the quantitative measurement of safety culture and to deepen their understanding of the measurability of safety culture elements.

Content Overview: Using the safety culture questionnaire obtained from Experiment 3, students independently designed and conducted quantitative safety culture measurements through SCAP (Safety Culture Analysis Program, an enterprise safety culture online analysis system developed by China University of Mining and Technology Beijing) [69]. This way, students are able to design different content about the safety culture measurement process, participants, and measurement methods. Finally, a safety culture quantitative measurement experiment is conducted to obtain the safety culture level.

Experimental steps

(1) Students design the quantitative measurement process of a safety culture.
(2) Students determine their measurement targets, sample sizes and sampling methods.
(3) Students conduct quantitative safety culture measurements using the safety culture questionnaire designed in Experiment 3.
(4) Students collect their questionnaires and output the measurement results.

Experiment 5: Analysis of safety culture measurement results

Purpose and Significance: To enable students to master the results analysis methods of safety culture quantitative measurement, including data analysis methods and graph reading abilities, and to master how to interpret the safety culture levels obtained from these measurements.

Content Overview: Based on the safety culture quantitative measurement data or graphs that they produce, students analyze their deeper meaning, such as the reasons for different safety culture quantitative measurement results among different categories or different working ages or levels of employees, and then interpret the measured safety culture levels.

Experimental steps

(1) Students generate the results of their quantitative measurements in Experiment 4.
(2) Students clarify the meaning of each data point in their measurement results.
(3) Students learn and master data analysis methods, analyze their measurement results and interpret their data graphs.
(4) Students interpret the deeper meaning of their data analysis results and the overall safety culture levels of their measured objects.
(5) Students complete their analyses and write reports on the analysis results.

Experiment 6: Safety culture training design

Purpose and Significance: To enable students to understand and master safety culture training processes, objectives, contents, forms, etc., to learn the means of implementing a safety culture and to further their understanding of the meaning of safety culture.

Content overview: After selecting the safety culture definition in Experiment 1, completing the design of the elements in Experiment 2, and then understanding the training needs based on the analysis of the safety culture measurement results in Experiment 5, the safety culture training content design can be carried out. First, we select the target of training and investigate and analyze the training needs of the target. Then, training objectives and plans are developed. Finally, the training content and form are designed to complete the training design.

Experimental steps

(1) Students find and select enterprises for their experimental designs.
(2) Students investigate and analyze training needs according to the Experiment 5.
(3) Students develop safety culture training plans (design training objectives, content, form, time, place, etc.).
(4) Students integrate their design contents and complete their safety culture training designs.

Experiment 7: Designing safety culture carriers

Purpose and Significance: To enable students to understand and master the expression of safety culture elements and deepen their understanding of the meaning of safety culture.

Content Overview: The carrier types include safety culture manuals, display boards, animations, workwear, stationery, sculptures, theme parks, literary programs, and safety activities. Students can choose any one of these to design a safety culture carrier.

Experimental steps

(1) Students learn the bases for the designs of safety signs (the basis for the level of laws and regulations, the basis for the hidden dangers of the workplace, the basis for the data on violations of the workforce, etc.).
(2) Students select safety culture elements or definition contents according to Experiments 1 and 2.
(3) Students learn and choose the contents of safety culture carriers according to Experiments 5.
(4) Students integrate their selected safety culture contents into their selected safety culture carriers to design and explain their design concepts.

Experiment 8: Safety culture evaluation indicators

Purpose and Significance: To enable students to understand the sources of safety culture evaluation, to distinguish the difference between safety culture quantitative measurement and safety culture evaluation and to master the safety culture evaluation methods, processes and designs of evaluation indicators.

Content Overview: This experiment enables students to understand the contents of the documents "Guidelines for the Building of Safety Culture in Enterprises" (AQ/T9004-2008) and "Assessment Standards of Enterprise Safety Culture Developing" (AQ/T9005-2008). Students design safety culture evaluation indicators based on the above documents to evaluate the role and results of safety culture.

Experimental steps

(1) Students distinguish the difference between safety culture quantitative measurement and safety culture evaluation.
(2) Students learn the safety culture evaluation processes and evaluation methods (refer to "Guidelines for the Building of Safety Culture in Enterprises" (AQ/T9004-2008) and "Assessment Standards of Enterprise Safety Culture Developing" (AQ/T9005-2008) for evaluation methods).
(3) Students select their enterprises for evaluation.
(4) Students identify the results of their enterprises' safety cultures.
(5) Students design safety culture evaluation indicators based on their results.
(6) Students evaluate the results of the safety cultures of their selected enterprises and obtain their evaluation results.

Experiment 9: The role of safety culture - accident case studies

Purpose and Significance: To help students understand the role safety culture plays in accident case studies and the meaning of safety culture. The purpose is to guide students to apply theoretical knowledge to solve practical problems and achieve the purpose of integrating theory with practice.

Content Overview: A database of accident cases can be designed for this experiment. The database contains many significant and representative cases. Students randomly select cases in the database and analyze the main causes of accidents in the cases. The accident analysis can be based on models such as the 24 Model [70]. From the accident case studies, the safety culture deficiencies/elements in a company are identified, and the application and role of safety culture in the company are better understood.

Experimental steps

(1) Students find and select the accident case to be analyzed in the database.
(2) Students learn how the safety cultures in their cases operate in companies.
(3) Students analyze the role of safety culture for enterprises in the accident case studies based on 24 Model.
(4) Students list the roles and elements of safety cultures via their analyses of the accident case studies.

Experiment 10: The similarities and differences in safety culture in accident cases

Purpose and Significance: To compare the similarities and differences of safety culture and safety culture elements in different enterprises among different accident case studies and deepen their understanding of the meaning of safety culture; it is also a test of students' understanding of safety culture.

Content Overview: Students discover the aspects of safety cultures embodied in enterprises from actual interviews or the literature. On the basis of Experiment 9, we further establish the relationship between the enterprise and its safety culture and compare the similarities and differences of enterprise safety culture in different cases.

Experimental steps

(1) Students find and select accident cases for analysis.
(2) Students compare various aspects and elements of the safety cultures of companies in different accident case studies.
(3) Students identify the definitions and base elements for safety culture building in accident case studies and compare them with those selected and designed in Experiments 1 and 2, comparing the strengths and weaknesses of each.

The above is the specific content of the 10 experimental courses in safety culture, and the specific experimental steps and other content of each experiment can be designed according to the actual situations.

Through the above 10 safety culture experimental courses, the definition of safety culture and its related contents are applied to the teaching of experimental courses in safety engineering majors. The combination of practical teaching and theoretical teaching can help students deepen their understanding of the meaning of safety culture and promote safety culture research as independent content within the experimental coursework of safety engineering majors. In addition, this is also an attempt to transform safety culture from scientific research to teaching research.

6. Results

In summary, the following results have been drawn.

(1) Based on the review, the current definition of safety culture is briefly divided into three categories: "the embodiment of safety concepts", "the synthesis of safety concepts and behaviors", and "the comprehensive theory of safety culture".
(2) Ten safety culture experimental courses are designed based on the study of safety culture definitions, and an "apple" is formed to show the correlation between them.
(3) The basis, purpose, and steps of the 10 safety culture experimental courses are described, completing the attempt to transform safety culture from scientific research to teaching research.

7. Conclusions and prospects

The research presented in this paper is innovative since safety culture has not yet been applied as independent content in the experimental course for safety engineering majors. Based on the definitions of three categories of safety culture, this paper has designed 10 safety culture experiments and explained the corresponding content and steps. This is an attempt to transform safety culture from scientific research to teaching research, which will help students understand the concept and meaning of safety culture more fully and promote the application of safety culture in the teaching of safety engineering experimental courses.

The current research of safety culture experimental courses in this paper is still at the theoretical stage. In the future, the safety culture experimental course designed in this paper can be applied to the regular teaching of safety engineering majors with the help of computer modeling, software creation, etc. For example, developing a computer system for the safety culture experiment course that would allow students to complete a series of experiments in this paper through the software we designed. The software can record the experimental data in the background so that the corresponding experimental process can be improved through the students' experimental data processing. In practical teaching, the feasibility and improvement direction of these 10 experimental courses can be further studied.

Declarations

Author contribution statement

Wei Jiang; Jiankai Zhou: Conceived and designed the experiments; Wrote the paper.

Huiyuan Su; Zonghao Wu: Analyzed and interpreted the data; Wrote the paper.

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Data availability statement

No data was used for the research described in the article.

Declaration of interest's statement

The authors declare no conflict of interest.

Additional information

No additional information is available for this paper.

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