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Review

Development of safety science in Chinese higher education

Jiangshi Zhang[a,*], Jing Fu[a,b], Hongyu Hao[a], Na Chen[c], Wenyue Zhang[a], Young-Chan Kim[d]

[a] College of Resources and Safety Engineering, China University of Mining and Technology Beijing, Beijing 100083, China
[b] Resources & Environmental Engineering College, Jilin Institute of Chemical Technology, Jilin City 132022, China
[c] School of Mechanics and Engineering Science, Zhengzhou University, Zhengzhou City 450001, Henan Province, China
[d] Innovative Durable Building and Infrastructure Research Center, Hanyang University, 55 Hanyangdaehak-ro, Sangnok-gu, Ansan 426-791, Republic of Korea

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ABSTRACT

Safety science is a distinct, multidisciplinary activity in the academic community with abundant scientific connotation. Safety Science in China, especially in Chinese higher education, has developed rapidly in the past 20 years and its development process is affected by some factors including national laws and policies, economic development and administrative system. The above-mentioned factors make safety discipline with distinct industrial characteristics.

In this paper, firstly, the development process and significant events of safety science in abroad and domestic is reviewed. Secondly, education condition about safety discipline in higher education institutions is analyzed, mainly including education institutes, research fields, curriculum provision, employment, vocational situation, and academic exchange. Then discussing how the three factors influence the development of safety discipline.

The results show that 1999 is a demarcation point for the development process of safety science in China. Until 2016, there are 183 higher education institutions established safety discipline with different research fields. The focus of safety professionals' cultivation has gradually expanded from technical competence to the promotion of comprehensive ability and quality. Influenced by economy, the number of universities establishing safety discipline decreased from southeast coast to central region, to western region, and its research fields are basically consistent with the local prop industries. Furthermore, in order to solve the main problem of single industrial research field of safety discipline, Chinese universities should propose new research directions, improve discipline contents and make further efforts to soften the industrial effect of safety discipline.

1. Introduction

Science is a means of producing knowledge about the world and how we can understand, assess, and manage this world (Okasha, 2002; Aven, 2014; Hansson, 2013). Safety science is an integral part of science, defined as a scientific discipline with a dedicated object of research and methodology (Stoop, 2017), which can provide methods to prevent incidents or accidents, and further reduce or avoid consequent personal injury, property loss, and environmental damage (Fu, 2015). In China, some scholars define safety science as follows: Fu (2015) proposed that safety science is the knowledge system about the occurrence and development rule of accident and means of preventing accidents. Wu (2016) argued that safety science is the discipline and knowledge system about the basic rules and its application of human physical and mental protection from the adverse effects or hazards of external factors. In a word, safety science as a scientific activity that has unique connotations is different from other science.

Higher education is of crucial importance for the development of a science as well as safety science, an emerging discipline (Fu, 2013). In fact, it's our hope that the professionals cultivating via higher education is able to improve safety conditions for company and society by making full use of what they have learned in the university. Arezes and Swuste (2012) mentioned that "an academic qualification is regarded as essential since those specialists must be capable to address new problems by applying knowledge and skills to situations not previously encountered". With the growing complexity of regulatory issues and the emergence of new problems like occupational stress, the need for HSE professionals to get a high level education is emphasized (Wybo and Van Wassenhove, 2016). Also, safety discipline in higher education needs to advance and improve continually.

Aven (2014) pointed out that safety science can be seen as a discipline, in which knowledge of safety related phenomena, processes, events, etc. and both parts are dependent on each other. Science has a wider relevance than its discipline. When given the meaning of a

* Corresponding author.
E-mail addresses: zjsh0426@163.com (J. Zhang), BQD1700102035@student.cumtb.edu.cn (J. Fu), haohongyu95@126.com (H. Hao), nchen@zzu.edu.cn (N. Chen), 18810393562@163.com (W. Zhang), yyoungchani@naver.com (Y.-C. Kim).

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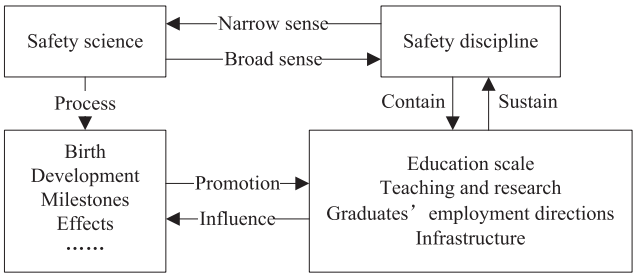

Fig. 1. Theoretical framework for the evaluation of a scientific discipline's development.

discipline, science becomes concrete and may be more relevant to higher education (Aven, 2014; Hollnagel, 2014). For the scientific discipline's development, a comprehensive and valid theoretical framework is essential to subsequent evaluation. Therefore, we have proposed a preliminary and simple evaluation framework for the development of safety science (see Fig. 1).

Stoop (2017) mentioned that safety science as a scientific discipline, no matter what domain it is related to: interdisciplinarity, problem-solving orientation and systems approach. Chinese scholar Liu (1988) had defined the nature of the safety discipline as "integration of arts and sciences, interdisciplinarity, industry comprehensive", Fu (2015) proposed that the nature of safety discipline also includes "accident prevention". The focus of the Chinese safety discipline is to prevent accidents and reduce personnel injuries including occupational injuries, property losses and environmental pollution (Fu et al., 2012).

To carry out accident prevention and management, statistics and analysis of accidents is foundational. In China, the number of accidents, casualties, serious injuries, minor injuries, acute poisoning and the direct economic loss are the comprehensive safety absolute indicators and variables that crucial to safety and deemed possible to scientifically observe and measure. Public pay more attention to the number of accidents and deaths, except which, serious and minor injuries are also concerned by enterprises (Fu et al., 2012). While, the US, Britain, Australia are focus on statistics of the health loss of the members of all social organizations in the country during the work of their organization, statistical contents refer to fatal injuries, injuries, lost work days instead of paying attention to the number, category, and economic loss of the accident itself (Fu et al., 2012; Bureau, 2013; Nishikitani and Yano, 2008; BLS, 2017). Because the variables of statistics and analysis are varied among countries, the main concerns of safety discipline are different.

All the time, the development of safety science attracts widespread interest from industry as well as academia because it is a scientific ideology and systematic theory for safety and accident. This paper performs a detailed analysis of the development of safety science, mainly regards to higher education in China. In the second chapter of this article, we do a literature review about the development process of safety science in abroad and domestic containing two time-lines of important events and introduce the current state of safety discipline in Chinese higher education including education institutes, research fields, curriculum provision, vocational situation, etc. We conclude with a discussion about the factors influencing the development of Chinese safety discipline in the third chapter.

2. Safety science in China

Over the decades safety science has made great achievements in the world, and its development is reviewed first. In the 19th century, occupational safety had attracted systematic attention (Swuste et al., 2010), and social legislation was slowly starting. During the late of the 19th to the beginning of the 20th century, scientific management was introduced, first in the United States, and later spreading over Western European countries. (Swuste et al., 2010). Occupational safety becomes a professional field of expertise, and accident-prone theory was developed in this period. Heinrich made contributions on causes of accidents, accident mechanisms and hidden costs of accidents during the interbellum (Gulijk et al., 2009). After the Second World War, a number of safety analysis techniques were developed such as FTA, FMEA, and HAZOP (Swuste et al., 2014). In this period, the epidemiological model of Haddon was developed. Winsemius put forward the theory of task dynamics, and through his research, human reliability analysis (Swain, 1964) and ergonomics (Singleton, 1960) began to enter the domain of safety science and accident prevention (Swuste et al., 2014). Then in 1970s, the knowledge on safety management began to take shape (Swuste et al., 2016). Major disasters in the 1980s generated knowledge on process safety, and soon process safety outplaces developments in occupational safety, which had been leading before (Swuste et al., 2017). Accidents were thought to be the result of disturbances in a dynamic system, a socio-technical system, rather than just human error (Swuste et al., 2017). After that many theories appeared, such as *"Swiss Cheese Model", "AcciMap", "HFACS", "STAMP", and "FRAM"* (Salmon et al., 2012, Rasmussen, 1997, Shappell and Wiegmann, 2012, Leveson, 2012, 2015). Furthermore, a great deal of attention had been paid to the contextual effects of organizational safety culture and safety climate (Petitta et al., 2017).

Academic research on Chinese safety science is relatively late. At the beginning of the 20th century, labor protection consciousness emerged. Scholars began to discuss about the issues on industrial hygiene and occupational diseases in the 1950s, and coal mine ventilation safety had been gradually in the spotlight. Systematic safety theories were introduced to China in the late 1970s. In the 1980s, scholars started to research on human reliability analysis and ergonomics. In the early 1990s, a large number of risks assessment research were carried in combination with safety evaluation methods and techniques. Since 2001, Fu and others set up a behavior-based organizational safety management model. More and more scholars begin to pay attention to behavioral safety.

2.1. The rise of safety science

When the British completed the industrial revolution, China was still in the late stage of feudal society (the Qing Dynasty). The scale of the handcraft industry began to expand due to the inflow of capital from Western countries (Jing, 2000; Sun, 2008). Manufacturing and mining were developing rapidly during that period. Relevant bureaus or companies in mining, ship manufacturing, ordnance manufacturing, etc., were established; and in order to reduce casualties, some management rules or regulations involved safety knowledge more or less were introduced from other countries (Sun, 2008). Moreover, the government ran schools to cultivate outstanding translators for learning advanced foreign technology, even sending them abroad for field study. Many scientific works were then translated and published. This could be seen as the earliest form of higher education that concerned safety science in China. The deplorable conditions of factories, long working hours, dangerous machines and the increased pressures of work and speed of production, created a heavy burden of occupational deaths among workers (Swuste et al., 2010). Under this condition, the *Factory Law*, as the earliest legislation on labor protection, was enacted in 1929, which marked the beginning of safety legislation in China (Peng, 2006). But it played hardly direct role due to the war in the following years. Faced with this, a civil organization called the Industrial Safety Association was established in 1933 (Liu, 1991), aiming to provide solutions to safety problems of production. The same year, the journal *Industrial Safety* was published. During this period, safety science was not mentioned as higher education discipline, and was hindered by various social factors.

Until 1949, the Ministry of Labor, who was in charge of the labor protection, was established and matters of safety were getting back on track. Meanwhile, local governments initially formed their own system