CAPTURING INSIGHTS: INTEGRATING DESIGN FOR SAFETY (DFS) EDUCATIONAL ELEMENTS INTO CURRICULA

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The significance of Design for Safety (DfS) in engineering and construction education is well-recognized for its role in shaping the skills of future designers. While scholars have explored integrating DfS into education, empirical evidence on educational elements for DfS remains scarce. This paper, part of a broader study on the DfS landscape in the Malaysian construction industry, delves into DfS educational learning. Through a questionnaire survey administered via DfS workshops, the study captures the importance of the DfS elements in five constructivist learning principles: content, learning outcomes, learning environment, learning domain, and pedagogical approaches across six different courses; Management Concepts; Construction; Design; Law and Regulations; Ethics; and Hazard and Control Measures. The findings indicate all five learning principles across six courses are important for DfS learning. This study extends the current literature on DfS in education, particularly focusing on the potential of DfS learning integration in related programs at educational institutions. This contribution could play a significant role in cultivating the DfS culture among future designers in the engineering, architectural, and construction domains.

Keywords: design for safety, education, Malaysia

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INTRODUCTION

The influence of design on construction safety was first highlighted in a 1987 publication by the Belgian National Action Committee for Safety and Health in Construction, authored by Lorent (1987). Since then, the concept of Design for Safety (DfS) has gained increasing interest as an innovative practice to address ongoing concerns in health, safety, and well-being (HSW) within the construction industry. Integrating the DfS concept into Architectural, Engineering, and Construction (AEC) education is recognised as a key approach to ensuring continuous improvements in this field. By incorporating DfS principles, future graduate designers can become more accountable for their responses to occupational HSW challenges. However, one of the main challenges in OSH education is to provide graduate designers with a solid foundation of safe design prior to real-world work experience (Hinze, 2000; Mann III, 2008). Integrating OSH in AEC educational programs to cater to the needs of safe design and instilling a commitment to preventive culture is often not addressed adequately in the curricula (Behm et al., 2014; Toole, 2017; Che Ibrahim et. al., 2021). Despite the current state of DfS practice gaining interest in different geographical contexts (e.g., Botswana (Rantshilo et al., 2022), Malaysia (Christermaller et al., 2022) and Vietnam (Phan and Zhou, 2023)), the issue of how to infuse DfS practice into the minds of future graduate designers through the AEC curricula remains elusive. Literature suggested that identifying the implications, challenges, barriers and positive attitudes toward DfS adoption can help with preparedness and diffusion of future designers (Gambatese et al., 2017).

The subject of DfS in education has shown increasing interest in both developed and developing nations in recent years (Che Ibrahim et al., 2022). In particular, the emphasis on the importance of DfS education in developing countries such as Malaysia, where DfS guidelines were introduced in 2017, has demonstrated that there is a significant lack of DfS education in the existing educational landscape in engineering or construction programs (Che Ibrahim et al., 2021). The recent report from the CIDB (2019) emphasises that the lack of DfS education may hinder the development of designer skills required for successful DfS implementation. Several local researchers (e.g., Christermaller et al., 2022) have noted that designers have shown significant interest in DfS, but their initial education regarding DfS is inadequate. This deficiency hinders their ability to promptly address HSW risks during the design phase. Samsudin et al. (2021) added that the absence of early DfS education has led to the disregard of architectural safety design concerns for end-user facilities, which can impede designers in carrying out their tasks efficiently.

Despite growing interest in DfS studies in Malaysia, there is still a dearth of empirical evidence demonstrating the integration of the DfS concept into the educational framework. The current level of integration prompts inquiries on the practicality of including the DfS practice as a component of educational instruction and learning in higher education. Therefore, the purpose of this article is to explore how DfS elements might be incorporated into the curriculum. Gaining an insight into the best practices of integrating the DfS education could give educational institutions a point of reference for fostering the growth of DfS subject integration and advancing DfS diffusion in Malaysia. Moreover, establishing the DfS curriculum will provide future designers with the HSW-conscious knowledge and skills for DfS practice.

DFS EDUCATIONAL LANDSCAPE

Implementing DfS practices is crucial to preventing accidents and injuries at construction sites. However, a significant barrier to DfS implementation is the lack of knowledge among designers regarding potential risks and hazards early in the design phase. This deficit often results from inadequate education and training in DfS practices (Toole, 2017). Recognising the pivotal role of DfS education, research has focused on evaluating the inclusion of DfS practice in curricula (Che Ibrahim et al., 2022).

Efforts to integrate DfS into curricula have gained momentum over the years. Initiatives aim to instill a commitment to DfS among designers during their education, emphasising the ethical responsibility associated with the profession. However, challenges persist, particularly in incorporating risk education into accredited engineering courses, as reported in the United Kingdom (Stacey et al., 2009). Innovative approaches to teaching health and safety in architectural schools highlight the need for diverse teaching methods to address safety and health concerns effectively. In European countries like Spain, there's a call for mandatory DfS courses in educational institutions to equip graduates with professional competencies. Despite some progress through Bologna degrees, the integration of occupational health and safety (OHS) into engineering and architecture curricula remains inadequate (Lopez-Arquillos et al., 2015). Similarly, in the United States, although some educational institutions offer courses on construction safety, the inclusion of DfS practices remains limited. Factors such as institutional pressures, inadequate teaching resources, and curriculum constraints hinder integration efforts (Din and Gibson (2019a). Australia has recognised the importance of including safe design concepts in engineering education, with initiatives providing educational resources for engineering students. However, there's a need to enhance the implementation of DfS principles in engineering curricula, particularly at the higher education level (Foley et al., 2016). Utilising virtual reality technology has shown promise in improving students' understanding of DfS processes and terminology (Marinelli et al., 2023). Emerging nations like Malaysia face substantial challenges in incorporating DfS courses into civil engineering and architecture schools. There's a need for structured strategies, technology-driven teaching, and competency enhancement among lecturers to address this gap effectively (Che Ibrahim et al., 2021).

Despite efforts to integrate DfS into engineering curricula globally, challenges persist, hindering widespread diffusion. Attention to integrating DfS into education is crucial for nurturing future designers' capabilities in safe design thinking. However, this integration requires changes to current educational frameworks among graduate designers before entering the professional realm.

DESIGN FOR SAFETY LEARNING MODEL

To contextualise AEC curricula in alignment with the DfS philosophy, Ismail et al. (2022) introduced the DfS learning framework, presented in Table 1. This model leverages five (5) constructivist learning principles, synergising with safe thinking design principles to foster competency progression in knowledge, skills, and experience (Terhart, 2003). The integration of DfS concept and practice into AEC curricula is facilitated by the DfS learning model's comprehensive framework, encompassing Content, Learning Outcomes, Learning Environment, Learning Domain, and Pedagogy Approach.

Table 1: The Design for Safety (DfS) Learning Framework

Monitoring & Control Measures	Hazard & Control Measures	Construction techniques; identifying hazard	To understand the safety hazards recognition and designing solutions by substitution of tools and system.	Critical thinking; Design thinking	Classroom; internship; research project; site visit; workshop	Lectures; Research; Training; Case studies; computer/ paper-based game
Risk Assessment	Ethics	Ethical role of the engineer	To understand the professional roles and its responsibilities of duty holder within the framework of DfS	Instilling commitment	Classroom	Lectures; Modules; Training
	Law & Regulations	Safety framework, legal and regulatory; public policy; legal duties	To understand the available laws and regulations based on the lifecycle of the project	critical thinking; forward thinking; leadership	Classroom; workshop	Lectures; Modules; Training
	Design	Safety in design; safe design in lifecycle concepts; identifying hazard; DfS concept and its constructability	To understand the designing for safety issues and design decision making based on DfS concept and principles; to instil safe design thinking	creative thinking; communicate effectively; decision thinking; leadership	Classroom; Workshop; Collaborative networking; internship; Case Studies	Lectures; Modules; Training; interactive software;
Identification of Risk & Hazard	Construction	Construction techniques; construction site safety; planning and operation	To address the construction technique in safest practice and create preventive safety culture through best practices and advanced technological tools	Systematic thinking; communicate effectively;	Classroom; Case Studies; Collaborative networking; Lesson Learned	Lectures; Modules. Training
	Management Concept	Concept of DfS; safety and risk hazard management; risk hazard assessment; lab safety	To understand the safety management and responsibility in managing risk	Critical thinking; investigative; leadership; systematic thinking;	Classroom; internship; laboratory; multimedia; MOOC; site visit; seminar; websites	Lectures; tutorials; visiting speaker
Principle of DfS Practice	***DfS Course***	***Learning Content***	***Learning Outcomes***	***Learning Domain***	***Learning Environment***	***Pedagogical Approach***

Moreover, the DfS transferable skillset, including creativity, problem-solving, and professional communication, encapsulates safe thinking design competencies, complemented by engineering mastery skills reinforced by DfS principles. This integration ensures tangible application in real DfS scenarios, supported by a comprehensive learning capacity encompassing safety and health, risk management, and monitoring and control measures. Consequently, the DfS learning model serves as a foundational roadmap for designing AEC curricula, cultivating a safe thinking design mindset among students to achieve intended learning outcomes

The central aspect of enhancing DfS curriculum development lies in its educational content, serving to harmonise the spectrum for a structured body of knowledge characterised by both rigidity and adaptability, facilitating the integration of students' experiential knowledge with authentic materials and tools (Terhart, 2003). Behm (2014) encourages for the incorporation of DfS principles, encompassing both conceptual and practical applications, as the foundational basis for designing DfS educational content. The primary objective is to operationalise DfS principles within curricula to strengthen students' awareness and proficiency in prioritising safety across the engineering design lifecycle (Hinze, 2004; Mann III, 2008; Behm, 2014; Toole 2017). Proficiency in DfS concepts accelerates the development of students' capacity for safe design thinking, thereby mitigating occupational hazards in the early stages of project development. Throughout the DfS learning trajectory, students are afforded opportunities to collaborate with stakeholders and cultivate shared responsibilities in hazard and risk management. Nevertheless, there remains a paucity of guidance concerning the construction of educational content for safety curricula (Popov et al., 2013; Toole, 2017). Thus, this study proposes a comprehensive DfS learning framework for AEC curricula, based on six (6) key DfS content derived from a content analysis of AEC education literature, including Management Concepts; Construction; Design; Law and Regulations; Ethics; and Hazard and Control Measures.

RESEARCH METHOD

In order to gain a comprehensive understanding of the how DfS practice might be incorporated into the curriculum, a quantitative methodology, in particular a questionnaire survey of academics and practitioners was undertaken. The questionnaire consisted of two sections. The first section aimed to gather demographic information from the respondents, while the second section covers questions on the importance of DfS educational elements across five learning principles in six different courses (Management Concept, Construction, Design, Ethics, Hazard and Control Measures, and Legislative Framework) to be integrated in civil engineering curricula. For this section, participants were asked to indicate the level of importance using a five-point Likert-scale (ranging from 1 = not at all important to 5 = extremely important).

The questionnaire survey was administered through two DfS workshops. By utilising workshops as a data collection mechanism, a higher level of engagement with participants (who are experts in the same field) can be achieved. Two separate DfS workshops were conducted for academics and practitioners in 2023, with a total of 20 participants in the first DfS workshop and 30 participants in the second DfS workshop. A booklet containing the introduction, objective of the study, and the questionnaire survey on DfS education was given to the participants in each of the workshops. Descriptive statistical analysis, including the mean and frequencies, was applied to the obtained data in Microsoft Excel and executed in IBM SPSS 26 Software.

In terms of the nature of participants' work organisations, there is a fairly balanced distribution between public and private entities, with private organisations slightly outnumbering public ones by 54% to 46%, respectively. Delving deeper into participants' area of work specialism, Civil Engineering and Construction emerge as the dominant, collectively constituting 84% of the total participants, while Architecture and Surveying represent smaller percentages at 14% and 2%, respectively. Regarding educational qualifications 56% of participants hold undergraduate degree, followed by master's degrees at 34% and a smaller proportion with PhDs (10%). Professional qualifications further reveal a notable prevalence of individuals bearing the title "Ts." (i.e., Professional Technologist) (38%) in contrast to "Ir." (i.e., Professional Engineer) (28%). Finally, the average years of experience stand at 10 years, indicating a sample of well-experienced participants.

RESULTS AND DISCUSSION

The section presents the results on the importance of DfS elements in five learning principles in six different courses to be integrated in civil engineering curricula. The Table 2 presents findings regarding the five DfS learning principles and six courses, as indicated by mean values and standard deviations. The six related course examined in the study are: Management Concepts; Construction; Design; Law and Regulations; Ethics; and Hazard and Control Measures

The analysis of the DfS learning principles underscores the critical role of course content in shaping participants' perceptions. The consistently high mean scores, ranging from 4.09 to 4.37 across various content areas such as construction, design, ethics, hazards and control measures, legislative and legal, and management concepts, indicate the relevance of having such courses within an engineering curriculum. The scores suggest that participants not only find the content comprehensive, which includes identifying hazards, professional ethics, and construction techniques, but also find it relevant to their professional needs. The specificity of the courses within each content area likely contributes to their relevancy, catering to the diverse knowledge requirements within the realm of safety design. For instance, by formulating comprehensive safety plans as part of project management strategies and being able to establish and adhere to safety protocols throughout project execution, employing the hierarchy of controls approach for problem-solving (Behm et. al., 2014; Jia and Gilbert, 2017), the introduction to construction methodologies can facilitate students interpreting a rational approach to executing tasks in the safest manner possible (Hinze, 2000).

In evaluating learning outcomes, the data reveals positive feedback between proposed course outcomes and participant satisfaction. Mean scores ranging from 4.08 to 4.34 indicate that participants perceive the courses as appropriate for delivering the intended learning outcomes across construction, design, ethics, hazard and control measures, legislative and legal, and management concepts. In further analysis of the specifics of learning outcomes, we observe a multifaceted approach aimed at empowering students with essential knowledge and skills. For instance, focusing on equipping students with the ability to recognise safety hazards and devise effective solutions through tool substitution and systemic alterations would empower individuals to identify and mitigate on-site hazards (Samsudin et. al., 2021). Another outcome that emphasises the understanding of professional roles and responsibilities within the DfS framework would foster profound comprehension of the construction safety ecosystem during the early design stages (Gambatese et al., 2017).

Table 2: The responses on the DfS learning principles and courses for DfS integration

DfS ***learning principles***	**Course**											
	Construction		Design		Ethics		Hazard & Control Measures		Legislative & Law		Management Concept	
	M	SD	M	SD	M	SD	M	SD	M	SD	M	SD
Content	4.28	0.644	4.35	0.730	4.37	0.741	4.35	0.667	4.21	0.757	4.09	0.775
Learning Outcome	4.14	0.534	4.08	0.756	4.33	0.682	4.29	0.727	4.34	0.727	4.29	0.728
Learning Environment	3.99	0.784	4.07	0.763	4.07	0.798	4.07	0.851	4.09	0.77	3.83	0.828
Learning Domain	4.06	0.701	4.19	0.696	4.13	0.804	4.32	0.692	4.13	0.764	4.23	0.723
Pedagogical Approach	4.08	0.737	4.20	0.746	4.02	0.781	4.03	0.837	4.17	0.791	4.07	0.812
Overall Mean	4.11		4.18		4.18		4.21		4.19		4.10	

Note: M = Mean Rating, SD: Standard Deviation

However, despite the apparent positive feedback on content delivery and learning outcomes, the learning environment presents an area for improvement. Mean scores ranging from 3.83 to 4.09 signal some dissatisfaction among participants regarding the atmosphere in which learning takes place. This discrepancy may stem from a variety of factors, such as their experience with classroom dynamics, interaction with instructors, or the physical learning environment during tertiary education. Cortes et al. (2012) further reinforce this notion by emphasising technological tools as exemplars for fostering a safer work environment, thereby streamlining construction processes during the learning activities. Moreover, the use of case studies and site visits could provide the students with real-life learning experiences using wider resources and tools (e.g., machinery, equipment, human resource management, and worksite organisation) to cultivate a culture of preventive safety consciousness among the students (Toole, 2017).

While participants perceive the courses to cover relevant learning domains effectively, as indicated by mean scores ranging from 4.06 to 4.32, it's essential to consider the breadth and depth of domain coverage especially in terms of its cognitive, psychomotor and affective domain. Lew and Lentz (2010) further elaborate that idealising the affective function of the leadership role during the design phase enables students to advocate for safer construction practices and engage stakeholders in hazard prevention through the incorporation of diverse construction techniques. Moreover, students are guided to develop systematic thinking by actively participating in cognitive and psychomotor learning activities related to identifying project-related hazards and implementing risk management strategies (Toole, 2017).

The positive reception of the pedagogical approach across courses, with mean scores ranging from 4.02 to 4.20, underscores the importance of effective teaching methods in facilitating learning. While these scores indicate overall satisfaction with instructional strategies, the slightly higher variability compared to other educational elements suggests room for improvement. Beyond traditional lectures, alternative teaching methods like active learning, cooperative learning, and case studies can be integrated into the curriculum to foster skill development aligned with learning outcomes (Stacey et al., 2009; Popov et al., 2013). Scholars recommend using technology-driven methods like simulation-based learning and serious games to engage students and promote safe design thinking, fostering a commitment to safety in occupational HSW and principles of DfS practices (Hayne et al., 2017; Din and Gibson, 2019b).

Overall, the analysis of DfS learning principles and related courses highlights both strengths and areas for improvement in promoting safety-conscious design practices within engineering curricula. The consistently high mean scores across various content areas underscore the importance and relevance of courses such as construction, design, ethics, hazard and control measures, legislative and legal, and management concepts in meeting participants' professional needs. However, while participants perceive the courses positively in terms of content delivery and learning outcomes, there's room for enhancement in the learning environment and pedagogical approaches. Addressing these aspects through technological tools, interactive learning experiences, and diversified instructional methods can contribute to fostering a more conducive learning environment and enhancing students' engagement and skill development in safety design. Using new teaching methods, such as simulation-based learning and serious games, along with focusing on affective and psychomotor learning domains can also help students become more committed to safety and better able to advocate for and carry out DfS principles.

CONCLUSIONS

This study has provided an overview of how DfS is included into the engineering curricula. It focuses on five DfS learning principles that are implemented across six distinct engineering courses. The opinion on the integration of the learning principles and courses was adequately captured via questionnaire surveys during two separate DfS workshops. Overall, the results suggest that while the DfS learning principles and related courses highlight their relevance and alignment with participants' professional needs, there are notable opportunities for improvement in the learning environment and pedagogical approaches.

The study confirmed the possibility of enhancing DfS practice in engineering curricula, which were previously reported in the literature, within the context of developing countries. Such understanding could provide Malaysian higher educational institutions with the reference to align the existing DfS-related guidelines with the identified elements and courses, enabling proper guidance and standards for engineering faculties or departments that embrace OHS education in their curricula. Furthermore, such integration could also facilitate the requirements on safety and health elements in one of the 12 program outcomes specified in the Malaysian

Engineering Program Accreditation Standard 2024 under the Engineering Accreditation Council (EAC).

Although there were some limitations, such as a small number of samplings, future research could broaden the scope of the study to include a larger sample size and explore a comparative view between academics and practitioners' wider construction-related domains, such as architecture, civil and structural engineering, mechanical engineering, electrical engineering, and quantity surveying. Additionally, investigations with educational institutions that have incorporated OSH elements into their curricula could provide more insights into how, why, and what the challenges and drivers are to further enhance the teaching and delivery of DfS practices.

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