Towards a Competency-based Vision for Construction Safety Education

Akeem Pedro*, Pham Hai Chien, Chan Sik Park

Department of Architectural Engineering, Chung-Ang University, South Korea.

Corresponding Author, Email : lanrepedro3@gmail.com

Abstract. Accidents still prevail in the construction industry, resulting in injuries and fatalities all over the world. Educational programs in construction should deliver safety knowledge and skills to students who will become responsible for ensuring safe construction work environments in the future. However, there is a gap between the competencies current pedagogical approaches target, and those required for safety in practice. This study contributes to addressing this issue in three steps. Firstly, a vision for competency-based construction safety education is conceived. Building upon this, a research scheme to achieve the vision is developed, and the first step of the scheme is initiated in this study. The critical competencies required for safety education are investigated through analyses of literature, and confirmed through surveys with construction and safety management professionals. Results from the study would be useful in establishing and orienting education programs towards current industry safety needs and requirements.

1. Introduction

Despite the consistent growth of global markets and emergence of cutting-edge technologies, construction sites remain among the most dangerous workplaces with extremely high accident and fatality rates [1]. Even though the industry only employs approximately 7% of the world’s workforce, it reports incident rates which double industrial averages [2], and accounts for 30-40% of fatalities [3]. Addressing this problem requires continuous efforts not only industry practice, but in education and academia as well. Safety training and education play a crucial role in cultivating knowledgeable, skilled and competent personnel, ready to face the safety demands of construction work. Construction students who will take health and safety related positions after graduation will be required to interact with workers, equipment and working conditions, bearing a major responsibility in fostering positive attitudes and encouraging safety directives to ensure site safety [4]. A high percentage of construction accidents occur as a result of human errors which can be proactively prevented through safety education [5]. However, current training programs have been criticized for being deficient in developing and strengthening crucial safety competencies [6]. Moreover, safety education efforts in tertiary institutions have been inadequate and ineffective in preparing students to meet the safety demands of modern construction sites [7]. It is of crucial importance that students who will become project managers, operations managers, safety managers and site advisors have the knowledge, skills, and competencies necessary for fostering safe and healthy construction work environments, and contributing to accident reduction efforts in the industry. In this regard, there is a need for a reformative shift, towards competency-based construction safety education.

In today’s increasingly complex and dynamic construction industry, graduates need to possess not only technical skills, but key competencies which contribute to organizational performance outcomes as well. Furthermore, with global competition and the multi-disciplinary nature of work in construction-related industries, it is important to educate new professionals to develop appropriate skills [8]. Considering the high risk nature of construction, and the poor safety record of the construction industry, educational programs should be designed to mirror the dynamic landscape of the construction industry, to ensure students are competent upon graduation [9]. Construction curricula typically include various outcomes derived to meet the perceived needs of industry [10]. However, since safety is usually a low priority among other learning outcomes [11], learners fail to develop the required safety competencies.
This can have grave consequences, as a lack of competency can lead to serious errors and negative results in terms of safety performance [12].

In light of these challenges, this paper proposes a vision for competency-based construction safety education, to bridge the gap between the competencies current pedagogical approaches develop, and those required for safety in practice. This study takes the first step to reorient construction pedagogy to build safety competencies and lead the industry towards a new construction safety paradigm. A research scheme is proposed, delineating how the competency vision can be achieved; and then critical competencies required for construction safety education are identified.

2. Towards Competency-based Construction Safety Education

This section discusses the vision of the study towards competency-based construction safety education. Firstly, a theoretical explanation of competency-based education is provided, then the vision for competency is described, illustrating the competency levels students are expected to reach, after graduation and industry experience. Lastly, a research scheme is provided, breaking down the steps and research issues which should be tackled in order to achieve the vision.

2.1 Theoretical Basis for Competency-based education

In line with an emphasis on “work-readiness” and learning outcomes, competence research has emerged from academic fields such as psychology and education [13]. The notion of “competency” refers to the knowledge, skills, attitudes and values that are necessary to successfully perform a particular activity or task [14]. Competency Based Education (CBE) is a learner centered, outcome based approach capable of reorienting educational processes towards demonstrated mastery and the application of knowledge and skills in the real world [15; 9]. CBE is performance oriented, placing emphasis on what students can do, as a result of learning [16]. Work in a range of disciplines has demonstrated that proficiency in particular competencies is associated with higher levels of performance [17]. Similarly, enhancing safety education to develop safety competencies would result in improved safety performance; and more desirable safety outcomes. In construction safety education, CBE can bridge the gap between industry safety requirements and graduates’ knowledge and capabilities.

However, due to construction curricula lacking means of effectively disseminating safety knowledge, and assessing learner’s safety proficiencies, it remains difficult to ascertain that construction graduates possess the competencies required for safe performance on the real jobsite. In response to these deficiencies, the CBE process is adopted, serving as a basis for establishing tertiary construction safety education. CBE is based on five core principles: 1) programs reflect valid competencies; 2) students can learn at variable pace; 3) effective learning resources are available; 4) competencies are explicitly mapped to learning outcomes and assessments; and 5) assessments are secure and reliable [15]. In order to reflect these principles, a competency-based program for construction safety education is: 1) based on specific industry-based competencies (which are identified in this study); 2) Web-based course delivery is proposed to afford flexible learning content accessibility; 3) effective learning resources are designed with a visualization-enhanced approach, to overcome the limitations of conventional educational approaches; 4) safety competencies are constructively aligned with learning activities and assessment measures; and lastly 5), web-based automatic and proctored assessment measures are proposed.

At the instructional level, CBE builds upon students’ base knowledge and affords learning experiences which build content knowledge, cognitive skills, abilities and values. Next, CBE affords integrated learning experiences, whereby students are required to synthesize knowledge, skills, and abilities consistently [16], in a context resembling that required in industry. For safety education, CBE should facilitate not only the acquisition of explicit safety knowledge and skills, but the cultivation of the implicit abilities, attitudes and values pertinent to construction safety as well. In addition, assessment is a critical element, and learners should only advance after demonstrating the competency necessary to perform a task in the realistic context [17].

2.2 Vision for Competency in Construction Safety Education
As illustrated in figure 1, this study proposes a long-term vision for safety competency, focusing on improving safety education and safety culture in the construction industry. Currently, majority of tertiary construction education programs do not include safety courses; hence, graduates lack safety knowledge and practical safety experience after graduation. In essence, they enter the construction industry as incompetent safety practitioners. This study proposes a research agenda aiming to move learners from the entry level (incompetent) to level 2 (competent), prior to employment in the industry. For learners to achieve safety competency, first a basic level must be reached, whereby learners possess a core knowledge of safety rules, regulations and common hazards. Following the basic knowledge level, learners need to not only develop skills, abilities and competencies such as hazard identification and safety communication; but also they need to demonstrate them, at the desired level. The scope of the current study focuses on deploying a CBE strategy with the support of advanced visualization technologies, and web-based modalities to elevate learners to “become competent” and ready to contribute to improving safety in the construction industry.

**Figure 1. Vision for construction safety competency**

Aside from tertiary education, continuous effort is also required in the actual industry, in order to reduce accidents and injuries; and improve the safety culture in the industry. As a future vision, construction graduates who have achieved competency (level 2), are expected to further influence organizational safety performance and safety outcomes, and become advanced safety practitioners (level 3), after they acquire further real industry experience, and develop the ability to guide and transfer knowledge in the workplace. Lastly, expert safety practitioners are expected to contribute even further to generate innovative ideas to tackle safety issues, motivate colleagues and workers to comply with safety requirements, and establish a safety culture at an organizational level.

2.3 Research Scheme to Achieve Vision

In order to achieve the vision for construction safety competency, this study proposes a research scheme to establish effective construction safety education. Based on the theory of constructive alignment [18], the scheme comprises of three key sections. Considering the lack of clarity and research on the safety requirements for construction graduates, the first section of the scheme focuses on identifying the safety learning outcomes (competencies) which are necessary to prepare construction management students for the safety demands of construction jobsites. This study focuses on executing this first step, and investigates the critical competencies for preparing learners for the real industry. Following this step,
learning activities which would support students to acquire and develop the safety competencies need to be designed. Instructional methodologies need to be designed to ensure students develop the necessary safety knowledge, skills and capabilities. In order to develop an effective educational approach visualization technologies are considered, along with web-based knowledge dissemination modalities to afford experiential and interactive didactic activities. Lastly, the third section considers what type of safety assessment would be necessary for students to demonstrate that they possess the required safety competencies, before entering the real construction industry. A novel visualization-enhanced safety assessment method is proposed, in order to afford authentic, context-based assessment, whereby learners can effectively demonstrate their safety competencies in simulated environments.

This study takes the first step in achieving this vision, by investigating the specific competencies that should be incorporated and delivered in tertiary construction education in order to prepare students for the modern safety demands of construction jobsites. These competencies serve as the foundation upon which a competency-based learning and context-based assessment contents will be established in future studies.

![Figure 2. Research scheme for safety competency vision](image)

### 3. Investigating Required Competencies for Construction Safety Education

In order to identify the required competencies for construction safety, literature, safety documents and accident records were analyzed; and then a survey was conducted to identify the competencies for improving safety outcomes. The investigation focused on the comprehensive range of competencies which are perceived to have an influence on construction safety performance. These included a broad spectrum of capabilities and expertise, such as technical (knowledge based) competencies, personal management, and interpersonal management competencies, and so on. The technical competencies such as Hazard Identification and Safety Inspection are based on Occupational Safety and Health Administration (OSHA) training requirements and standards [19], Korean Occupational Safety and Health Agency (KOSHA) rules and regulations, and the KOSHA Standard Risk Evaluation Model [20]. On the other hand, managerial and personal competencies were initially identified through related literature. Subsequently, surveys were conducted to ascertain their current significance.

As depicted in table 1, thirty experienced construction management and safety professionals participated in interview surveys to rate and identify the critical competencies, with a 5-point Likert scale (5 – Critical, 4 – Very important, 3 – Important, 2 – Unimportant, 1 – Completely Unimportant).
In order to improve the credibility and reliability of results, participants were allowed to maintain anonymity in their responses, and they were required to possess a minimum of 5 years practical experience in either construction or safety management.

**Table 1.** Specialization and experience of respondents.

| Specialization             | Average Experience |
|----------------------------|--------------------|
| Construction Management    | 21 (70%) 8 Years   |
| Safety Management          | 9 (30%) 10 Years   |

Table 2 presents the comprehensive list of twenty-nine competencies identified and the ratings for their perceived importance. Respondents identified hazard identification, safety inspection, compliance with safety regulations, site safety planning, accident avoidance strategies, hazard evaluation and control as the most important competencies for construction safety education, all with standard deviations less than 1. These are the competencies which have the highest impact on accident and injury prevention on the construction jobsite. The competencies perceived to have the lowest influence on safety included: conceptual safety skill, which is defined as the ability to see the organization as a whole, in the context of safety; relationship management; and analytical and conceptual thinking. Analytical and conceptual thinking was the only criterion predominantly considered unimportant (M: 2.97, SD: 0.77), while all other 28 competencies were deemed significant.

**Table 2.** Competencies for construction safety in order of importance.

| Rank | Competency                  | Mean | S.D. | Mode |
|------|-----------------------------|------|------|------|
| 1    | Hazard Identification       | 4.7  | 0.66 | 5    |
| 2    | Safety Inspection           | 4.6  | 0.56 | 5    |
| 3    | Compliance with Regulations | 4.5  | 0.63 | 5    |
| 4    | Hazard Control              | 4.5  | 0.68 | 5    |
| 5    | Hazard Evaluation           | 4.47 | 0.86 | 5    |
| 6    | Site Safety Planning        | 4.4  | 0.6  | 5    |
| 7    | Self-Awareness              | 4.37 | 0.8  | 5    |
| 8    | Accident Avoidance Strategies | 4.33 | 0.75 | 5    |
| 9    | Accident and Error Analysis | 4.3  | 0.75 | 5    |
| 10   | Safety Communication        | 4.3  | 0.79 | 5    |
| 11   | Near-miss reporting         | 4.2  | 0.61 | 5    |
| 12   | Emergency Management        | 4.13 | 0.73 | 5    |
| 13   | Commitment to safety        | 4.06 | 0.69 | 5    |
| 14   | Self-Control                | 3.97 | 0.85 | 5    |
| 15   | Initiative                  | 3.93 | 0.9  | 5    |
| 16   | Interpretation Skills       | 3.9  | 0.85 | 5    |
| 17   | Conflict Resolution         | 3.87 | 0.68 | 5    |
| 18   | Knowledge of Work Tasks     | 3.7  | 0.74 | 5    |
| 19   | Teamwork                    | 3.67 | 0.66 | 5    |
| 20   | Discipline                  | 3.6  | 0.72 | 5    |
| 21   | Self-Confidence             | 3.57 | 0.9  | 5    |
Teambuilding skills & 3.57 & 0.77 & 5 \\
Social Awareness & 3.53 & 0.93 & 5 \\
Leadership & 3.47 & 0.81 & 5 \\
Interpersonal Understanding & 3.47 & 0.63 & 5 \\
Corrective Work Allocation & 3.47 & 0.77 & 5 \\
Conceptual Safety Skill & 3.27 & 1.11 & 5 \\
Relationship Management & 3.17 & 0.98 & 5 \\
Analytical and Conceptual Thinking & 2.97 & 0.77 & 4 \\

There is an urgent need to incorporate the aforementioned safety competencies into construction education, in order to bridge the gap between real industry practice and academia, and equip students with the competencies necessary to ensure safety on the jobsite. In addition, noteworthy comments from respondents are as follows:

- **Respondent 5:** With effective instructional tools, strategies, and managerial support, the proposed vision for competency-based safety education can contribute to enhancing overall safety culture in the construction industry in the future.

- **Respondent 7:** “Current training programs in industry make use of pictures and videos. The proposed visualization-based approach could be useful in industry too, if it can cover the broad range of identified competencies.”

- **Respondent 23:** “It is necessary to incorporate the identified safety competencies into construction programs, especially competencies related to hazard identification, response and control. These have the most direct impact on safety performance.”

### 4. Discussion and Conclusion

Construction projects are extremely complex, requiring highly skilled and competent professionals for their safe and timely execution. Hence, graduates who take up front-line positions such as project managers, safety managers and supervisors play a pivotal role in improving safety performance. However, safety knowledge, skills and proficiencies are currently severely underrepresented in tertiary construction curricula. As a result, graduates enter the construction industry without the competencies necessary to ensure jobsite safety. It is critical that construction education facilitates learning experiences which develop students’ safety skills and competencies to the levels necessary to meet modern project safety requirements.

In response to these issues, this study proposes competency-based vision for construction safety education, focusing on cultivating the safety competency of future construction personnel based on industry specific standards and requirements. Competency-based education is introduced as a reformative theory to transform construction safety education in order to equip students with safety competencies necessary to improve construction safety performance. The competencies required for safety education are investigated and verified through interview surveys with construction and safety management professionals. These would serve as a basis for establishing competency-based instructional and assessment strategies, and educational content development in future studies. Future research will explore the critical affordances for effective competency based safety education and the instructional considerations for developing a competency-based safety course. In addition the development of “proof-of-concept” systems and frameworks will be necessary in order to evaluate the novel competency-based didactic approaches. Unless there are radical changes in construction education to enhance the safety competency of personnel, the construction industry will continuously be plagued by persistent accidents, injuries and fatalities. This paper provides an overarching theory as a new perspective for construction safety competency and also a framework to guide holistic reform of construction safety education. The frameworks and theories developed in this paper will aid educators and course developers in establishing safety education in tertiary construction curricula, and also help to align construction safety education with industry practice.
References

[1] Le Q T, Pedro A & Park C S 2014 A Social Virtual Reality Based Construction Safety Education System for Experiential Learning Journal of Intelligent & Robotic Systems 79 (3-4) 487-506.

[2] Pedro A, Lee D Y, Hussain R & Park C S 2017 Linked Data System for Sharing Construction Safety Information In ISARC Proceedings of the International Symposium on Automation and Robotics in Construction Vol 34 Vilnius Gediminas Technical University Department of Construction Economics & Property.

[3] Sunindijo R Y & Zou P X 2013 Conceptualizing safety management in construction projects Journal of Construction Engineering and Management 139(9) 1144-1153.

[4] Wybo J L & Van Wassenhove W 2015 Preparing graduate students to be HSE professionals Safety Science 81, 25-34.

[5] Pham H C, Pedro A, Le Q T, Lee D Y & Park C S 2017 Interactive safety education using building anatomy modelling Universal Access in the Information Society 1-17.

[6] Antonio R S, Isabel O M, Gabriel P S J & Angel U C 2013 A proposal for improving safety in construction projects by strengthening coordinators’ competencies in health and safety issues Safety science 54, 92-103.

[7] Pedro A, Le Q T & Park C S 2015 Framework for Integrating Safety into Construction Methods Education through Interactive Virtual Reality Journal of Professional Issues in Engineering Education and Practice 142(2) 04015011.

[8] Rahimian F P, Arciszewski T & Goulding J S 2014 Successful education for AEC professionals: case study of applying immersive game-like virtual reality interfaces Visualization in Engineering 2(1) 4.

[9] Benhart B L & Shaurette M 2014 Establishing New Graduate Competencies: Purdue University's Construction Management Curriculum Restructuring International Journal of Construction Education and Research 10(1) 19-38.

[10] Walther J & Radcliffe D F 2007 The competence dilemma in engineering education: Moving beyond simple graduate attribute mapping Australasian Journal of Engineering Education 13(1) 41-51.

[11] Jaeger M & Adair D 2012 “Construction Safety Simulations and Students’ Perception of Stress.” 40th SEFI Conference-Engineering Education 2020: Meet the future.

[12] Chang S H, Chen D F & Wu T C 2012 Developing a competency model for safety professionals: Correlations between competency and safety functions Journal of safety research 43(5) 339-350.

[13] Azevedo A, Apfelthaler G & Hurst D 2012 Competency development in business graduates: An industry-driven approach for examining the alignment of undergraduate business education with industry requirements The International Journal of Management Education 10(1) 12-28.

[14] Dubois D D 1998 The competency casebook: twelve studies in competency-based performance improvement Human Resource Development.

[15] Johnstone S M & Soares L 2014 Principles for developing competency-based education programs Change: The Magazine of Higher Learning 46 (2) 12-19.

[16] Guthrie H 2009 Competence and Competency-based Training: What the Literature Says National Centre for Vocational Education Research Ltd. PO Box 8288 Stational Arcade Adelaide SA 5000 Australia.

[17] Hayton J C & Kelley D J 2006 A competency-based framework for promoting corporate entrepreneurship Human Resource Management 45(3) 407-427.

[18] Biggs J 1996 Enhancing teaching through constructive alignment Higher education 32(3) 347-364.

[19] Occupational Safety and Health Administration 2015 Training requirements in OSHA standards and training guidelines https://www.osha.gov/Publications/osha2254.pdf

[20] Korean Occupational Safety and Health Agency 2011 Risk Evaluation Model http://english.kosha.or.kr/english/main.do