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INCORPORATING A RESILIENT INFRASTRUCTURE DESIGN STRATEGY, SAFE-TO-FAIL, INTO ARCHITECTURE/ENGINEERING/CONSTRUCTION (AEC) CURRICULA

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Abstract

With the increasing demands for resilient developments due to the continuing threats of natural and man-made disasters, Architecture/Engineering/Construction (AEC) education shall be at the forefront of preparing future workforces with advanced knowledge about sustainable and resilient designs. Given that, traditional defense structures alone can hardly protect the vulnerable communities, particularly against flood disasters, there is a pressing need to explore adaptive and innovative solutions and embrace them in AEC education. Safe-to-Fail is such a resilient design strategy that anticipates failures during infrastructure systems planning, thus accommodating innovative strategies and reducing the impact of natural disasters. Therefore, this research advocates incorporating the resilient Safe-to-Fail concept in the AEC curricula to cultivate infrastructure resilience knowledge among the future minority engineering workforces. The objectives of this study are to: (1) identify the factors influencing AEC students' perceptions towards learning Safe-to-Fail; and (2) investigate students' pedagogical preferences to incorporate the Safe-to-Fail concept in AEC curricula. To achieve these objectives, the study developed a framework including a comprehensive lecture on Safe-to-Fail and its applications followed by an interactive discussion session and a survey to capture students' experiences, expectations, and perceptions. The framework was implemented in a cross-listed Sustainable Approach to Construction course in an educational institution located in a hurricane-prone state. 55 AEC students who were registered in the course participated in the framework and shared their level of interest as well as a preferred pedagogical approach to integrating the Safe-to-Fail concept in the curricula through the survey. The findings indicated that most of the participating students, mainly minorities, preferred to learn the Safe-to-Fail concept as a portion of an elective course and that the choice of learning such emerging concept is significantly correlated to the student's age, duration spent in the program, and prior knowledge of Safe-to-Fail. This study fills in the literature gaps through shedding light on the significance of integrating emerging and effective design strategy Safe-to-Fail as part of the teaching effort to AEC students particularly the underrepresented minorities. Integrating Safe-to-Fail in the curricula can foster disaster resilience knowledge and skills within the AEC minority students thus nurturing their ability to contribute to a sustainable and resilient built environment as well as provide an edge for future competitive careers.

Keywords: Natural disasters; Infrastructure systems; Construction education; Safe-to-Fail; Resilient design

Introduction and Background

Natural hazards have consistently impacted cities across the world causing infrastructure systems failures, which threatened the health and safety of our communities. Due to the growing frequency and intensity of extreme weather events, the governments have endured immense financial stresses to recover and manage the disaster damages. According to the report by CRED [1], the statistics of natural disasters indicate a major leap in 2019 with recorded 396 disasters compared to the period from 2009 through 2018 with 343 natural disasters. The report also highlighted that the 2019 disasters affected almost 95 million people and caused 103 billion US$ economic losses across the world [1]. Hence proper adaptation and mitigation approaches to enhance the resilience of the vulnerable regions and the critical infrastructure systems must be researched, assessed, and adopted to tackle and reduce the disaster damages. With the growing necessity and significance of resilient developments, it is essential to prepare future construction managers and engineers with knowledge and skills of innovative design and development approaches for resilient infrastructure systems. Therefore, Architecture/Engineering/Construction (AEC) education must incorporate infrastructure resilience topics into courses and curricula which can help the graduates to expand their knowledge and involve themselves in the new paradigm of resilient infrastructure systems design in their career. This study introduces an emerging and effective resilience design concept Safe-to-Fail to the AEC minority students to improve their knowledge of infrastructure resilience against natural disasters, which can support critical decision-making during the design, construction, and maintenance of the infrastructure systems.

The current literature highlights that Architecture/ Engineering/ Construction (AEC) curricula are predominantly focused on the conventional fail-safe method which follows the standard codes to design an infrastructure system [2]. However, such designs consider the forecasted intensity of natural disasters that are hardly reliable as climate change continues [3]. Moreover, a higher factor of safety to build robust structures that can sustain adverse events may be economically unfeasible. Thus, it is critical to investigate innovative and economically viable design approaches to build disaster-resilient infrastructure systems. Safe-to-Fail is such an urban planning strategy that focuses on less expensive ecological solutions and reduces dependency on engineering resilience, i.e., traditional structures. The Safe-to-Fail design approach can potentially minimize infrastructure damages during natural disasters [4] and provide enhanced protection for disaster-prone communities, particularly in coastal flood-prone areas. Although literature highlighted Safe-to-Fail as an effective disaster adaptation approach, particularly for urban flooding [5]–[7], there remains a gap to educate future engineering and construction professionals about the significance of Safe-to-Fail particularly in the domain of coastal flood resilience improvement strategies. Therefore, a paradigm shift in traditional AEC coursework is necessary, by incorporating the infrastructure resilience concept, Safe-to-Fail through an effective learning approach to prepare future engineers for managing the infrastructure assets from the threats of natural disasters.

With the increasing demand for the resilient design of infrastructures, Safe-to-Fail strategies have been demonstrated as an effective solution, particularly to adapt and minimize flood disaster damages. Some of the leading Safe-to-Fail examples within the US are the Green Streets program in Portland, Oregon, sewerage systems in the Green Alleys program in Chicago, Illinois; the Staten Island Bluebelt in New York supporting urban drainage, Indian Bend Wash, which is a bio-retention basin consisting of parks, golf courses, and other activities in Phoenix, Arizona [4]. These solutions focus on ecological resilience and can effectively reduce the social, economic, and environmental impacts of infrastructure systems on the built environment. Moreover, Green Infrastructure (GI) and Low Impact Development (LID) are the most widely implemented Safe-to-Fail solutions in urban landscape design that have the potential to mitigate flood disaster damages [8]. However, the existing codes and standards are yet to be aligned to embrace such emerging concepts as the Safe-to-Fail solutions. Thus, introducing the Safe-to-Fail concepts to the AEC students can nurture an efficient platform to develop interdisciplinary knowledge including civil engineering, urban planning, landscape design and so on that facilitates implementing Safe-to-Fail solutions. Moreover, incorporating such concepts in the curricula can foster collaborative problem-solving skills among the students which are critical for successful adaptation against coastal flooding [9]. Therefore, AEC education can promote developing resilient coastal built environment through embracing the infrastructure resilience design concept Safe-to-Fail in the curricula.

Although AEC education has incorporated sustainability topics for a while now, resilience concepts are yet to be nurtured among professionals through education. Sustainability of civil infrastructure aims to reduce social, economic, and environmental impacts while controlling resource consumption whereas infrastructure resilience aims to achieve higher reliability, fast recovery, and lower risk during unfavorable events [10]. Although National Architectural Accrediting Board (NAAB) highlights that a holistic understanding of resilience principles is required to mitigate climate change impacts by future architects [11], the recent versions of the Accreditation Board for Engineering and Technology (ABET) and the American Council for Construction Education (ACCE) are yet to emphasize on such criteria in construction and civil engineering program standards [12], [13]. Studies showed that engineering and construction management students tend to have a less conceptual understanding of resilience compared to sustainability due to the lack of inclusion of such topics in the curricula [14], [15]. Therefore, it is critical to integrate resilience design concepts in the curricula to foster the AEC students' interest in infrastructure resilience as well as to develop a resilient built environment. The American Society for Civil Engineers (ASCE) highlighted that future engineers must possess the knowledge and skills related to resilient solutions that can positively impact economic and environmental contexts [16]. Thus, exposure to effective pedagogies that integrate Safe-to-Fail in the curricula can prepare the future workforce to utilize such profound knowledge in the professional world.

Higher education can play a significant role in disseminating critical emerging concepts to the students thus developing skilled professionals to serve our communities efficiently [17]. Therefore, such education can facilitate a better understanding of the efficacy of resilient infrastructure systems among AEC students. Very few studies have focused on educating students about resilient infrastructure design solutions against flood disasters. For instance, Lopez del Puerto et al. [18] developed an interdisciplinary program based on a hurricane case study research model to teach sustainable and resilient solutions for infrastructure systems. Pagán-Trinidad et al [19] adopted various educational approaches through courses, seminars, research projects, and so on to educate students, professors, professionals, and the general public for developing resilience of existing and new infrastructure systems against coastal hazards. Salzman et al. [20] incorporated infrastructure sustainability and resilience conceptual threads from first-year through senior design to the existing courses. Although these studies have adopted different teaching approaches to educating resilience concepts, there remains a gap in introducing resilient urban design concepts, Safe-to-Fail to the AEC students, and assessing their interest to learn such concepts through their curricula. To bridge this gap, this study implements a framework that fostered the students' understanding of the Safe-to-Fail concept and its significance as well as shares their level of interest to learn this concept through the AEC curricula. Additionally, this study identifies possible pedagogical strategies based on students' preferences that can effectively support AEC curricula and can boost students' knowledge and skills in planning and budgeting for Safe-to-Fail projects.

Methodology

This research seeks to study the insights of Architecture/ Engineering/ Construction (AEC) students in learning resilient, Safe-to-Fail, design strategies through their curricula. The study investigates the factors, that influence students' interest to learn such novel and emerging concepts. The study also reflects the students' preferences to develop a pilot pedagogical approach, to integrate such emerging resilient topics in the AEC curricula. Therefore, the study developed a framework as shown in Figure 1 that was implemented in a cross-listed Sustainable Approach to Construction course under construction management program in the Fall 2020 semester. Registered students for this course were from architecture, engineering, and construction majors who participated in this study. The implemented framework included a comprehensive lecture that introduced the participating AEC students to the Safe-to-Fail design concept, its potential in building resilient flood defense infrastructures, and practical examples of Safe-to-Fail strategies. The lecture also explained the difference between traditional fail-safe and Safe-to-Fail design methods in building flood defense structures. The framework instruments included an interactive discussion session followed by a survey. The discussion session allowed the students to interact with the authors so that they have a better understanding of the overall concept. Finally, the questionnaire survey was conducted to capture the students' views of learning and integrating the Safe-to-Fail concept in the AEC curricula.

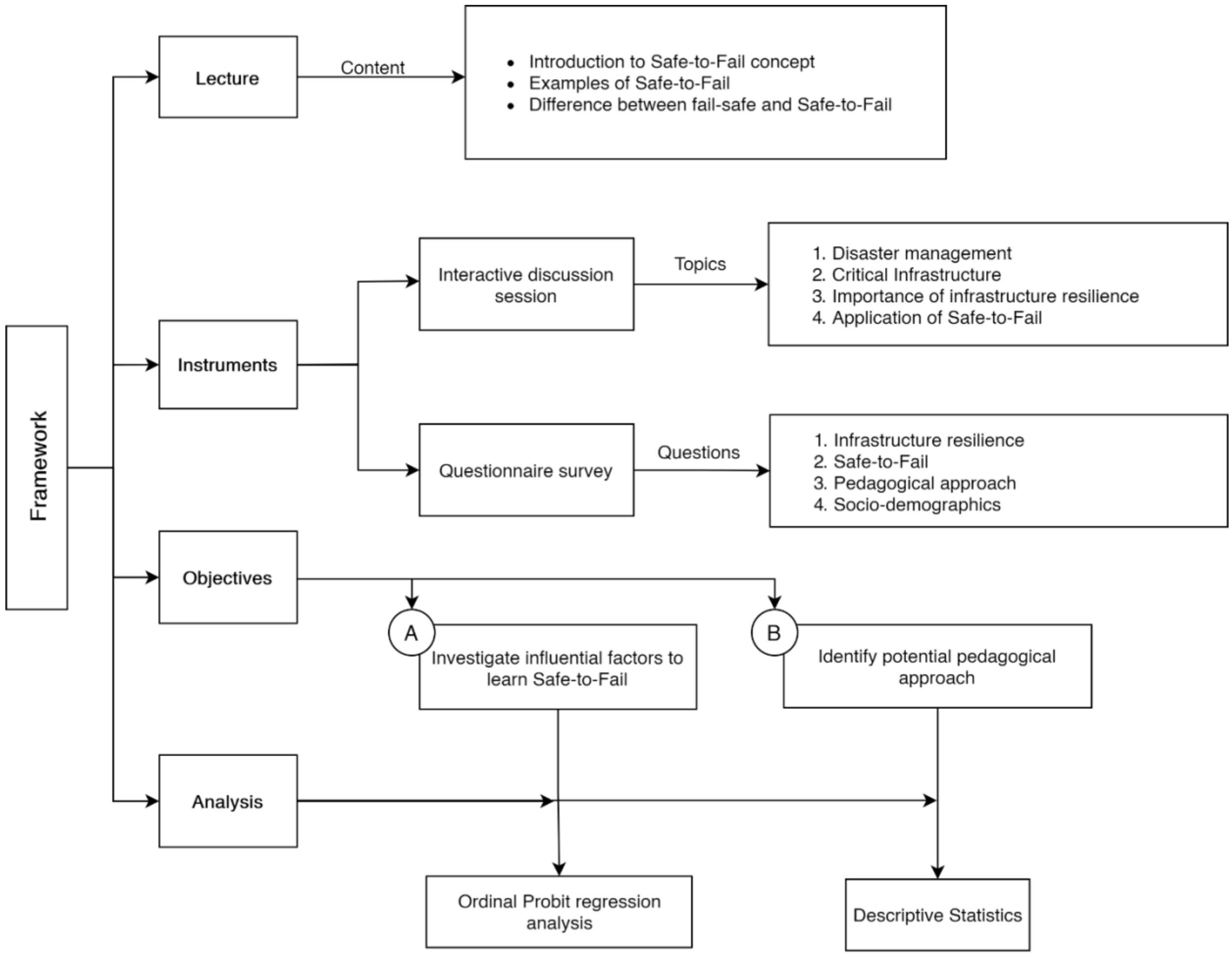

Figure 1: Framework implemented in the study

Survey Design

The study developed a questionnaire survey using an online platform Qualtrics. The authors designed the survey based on a literature review. The questionnaire was divided into two sections. The first section included multiple-choice questions that covered three important areas: (1) knowledge of infrastructure resilience; (2) knowledge of Safe-to-Fail concept including their interest to learn such concepts and the reasons behind their choices and (3) potential pedagogical approaches such as core/elective and complete/partial course. The second section of the questionnaire consisted of socio-demographic questions that reflected the surveyed 55 undergraduates and graduate AEC students' background information. The survey was administered at an educational institution located in a hurricane-prone state thus the respondents were assumed to have prior experience and exposure to natural disasters thus providing valuable insights to the study. Given that there aren't many research that focused on minorities and their insights towards learning resilient, Safe-to-Fail, design strategies through curricula, this research also focused on assessing the student data including students' ethnicity and racial backgrounds to provide an inclusive perspectives of the student's preferences.

The study utilized the Ordinal Probit regression model to identify the significant factors that influenced students' level of interest to learn the Safe-to-Fail concept. The authors used SPSS software to develop the regression model. The outcome of the dependent variable 'AEC students' interest to learn the Safe-to-Fail concept' has ordinal values (extremely unlikely, neither likely nor unlikely, somewhat likely, and very likely), therefore this study selected the Ordinal Probit regression method for the analysis [21].

The relationship between the influencing independent variables and the latent measure of the level of interest can be written as the following regression equation.

$$y_i^* = X_i\beta + \varepsilon \tag{1}$$

where y_i^* is the underlying latent variable that indexes the interest level of the ith participant to learn the Safe-to-Fail concept; X_i is a (k x 1) vector of explanatory variables; β is a (k x 1) vector of unknown parameters, and ε is the random error term that is assumed to be independent and normally distributed across i individuals. This equation implies that a unit change in X_i will change y^* by β unit considering all other variables as constant. The observed level of interest, y_i is determined from the following equation.

$$y_i = \begin{cases} 1\ if -\infty \leq y_i^* \leq \mu_1 (Extremely\ Unlikely\ to\ learn\ Safe-to-Fail) \\ 2\ if\ \mu_1 \leq y_i^* \leq \mu_2 (Neither\ likely\ nor\ unlikely\ to\ learn\ Safe-to-Fail) \\ 3\ if\ \mu_2 \leq y_i^* \leq \mu_3 (Somewhat\ likely\ to\ learn\ Safe-to-Fail) \\ 4\ if\ \mu_3 \leq y_i^* \leq \mu_4 (Very\ likely\ to\ learn\ Safe-to-Fail) \end{cases} \tag{2}$$

Where μ_i (i=1,2,3,4) is the unobservable threshold parameter that relates the latent measures y_i^* with their observed counterparts y_i in an ordered-response manner. Since this is a pilot study for integrating Safe-to-Fail in the curricula, the confidence interval is assumed to be 90% for the regression analysis. Additionally, the study conducted multiple descriptive analyses to understand students' perception of the Safe-to-Fail concept as well as investigate potential pedagogical approaches to integrate such concepts in the AEC curricula.

Results and Contribution to Knowledge

In general, this research seeks to study the insights of Architecture/ Engineering/ Construction (AEC) students in learning resilient, Safe-to-Fail, design strategies through their curricula and the fills in the gap of focusing on minorities and their perspectives thus providing more inclusive research results. This section presents the analysis and results of the survey responses obtained from the 55 AEC students who participated in the study. The survey respondents were registered students in a cross-listed Sustainable Approach to Construction course and consisted of 69% male and 31% female with various races including Asian, African American, Hispanic which indicates the heterogeneity of the sample [22]. Thirty-five participants were working in the AEC industry during the study and 49 respondents had previous working experience in the industry. Table 1 presents the detailed socio-demographic profiles of the participants.

Table 1: Students' Socio-demographic Profiles, n=55

Variables	Categories	Frequency	Percent	Variables	Categories	Frequency	Percent
Age	18-22	19	32.2	Current work status	Yes	35	59.3
	23-26	18	30.5		No	20	33.9
	27-30	2	3.4	Work experience in Construction Industry	No experience	6	10.2
	30-33	10	16.9		Less than a year	11	18.6
	More than 33	6	10.2		1-2 years	12	20.3
Ethnicity	Hispanic	38	64.4		3-5 years	12	20.3
	Non-Hispanic	12	20.3		5-7 years	9	15.3
	Other	5	8.5		More than 7 years	5	8.5
Race	Asian	6	10.2	Academic status	1st semester	4	6.8
	White	41	69.5		1 year	12	20.3
	African American	3	5.1		2 years	14	23.7
	Native Hawaiian or Pacific Islander	1	1.7		3 years	15	25.4
	Other	4	6.8		4 years	9	15.3
Gender	Male	38	64.4		More than 4 years	1	1.7
	Female	17	28.8	Student status	Local Student	45	76.3
					International Student	10	16.9

This study utilized the Ordinal Probit regression analysis to identify the significant factors that influence students' interest level for learning the Safe-to-Fail concept. Table 2 presents the coefficients and p-values of the independent variables considered in this study. The results show that Age, Academic status, and Source of Safe-to-Fail knowledge are statistically significant predictors of students' interest to learn Safe-to-Fail at a 90% confidence level. The coefficient of determination (R^2) value is 0.413 which indicates that the model can predict about 41.3% variability in model. The three intercepts $\boldsymbol{\mu}1$, $\boldsymbol{\mu}2$, $\boldsymbol{\mu}3$ indicate that there are four categories in the dependent variable and their differences manifest that the ordered categories (extremely unlikely, neither likely nor unlikely, somewhat likely, and very likely) are accurate and vice versa. The results indicate that the students' source of Safe-to-Fail knowledge, i.e., academia, work, or others is the most salient predictor of their interest to learn Safe-to-Fail followed by Academic

Status and Age. The positive coefficient of the source of Safe-to-Fail knowledge indicates that students who learned about Safe-to-Fail from academia are more interested to learn this concept through their AEC education compared to students who learned this concept from other sources such as work, articles, and so on. Similarly, the positive coefficient of academic status indicates that the shift from the "less than 4 years" category into "4 years or more" enhances students' interest. Thus, it can be inferred that senior students who have been enrolled in the program for a longer period are more interested to learn the Safe-to-Fail design concept. Likewise, students' age has a positive coefficient which indicates that older students have a higher interest to learn the resilient Safe-to-Fail concept. This may be because senior and older students had more exposure to a real-world work environment which influenced them to learn such resilient concepts and provide them an edge in the competitive construction environment. Thus, considering such proactive and pragmatic mindsets of future engineers, the Safe-to-Fail concept could be tailored in the AEC program curricula along with real-world examples so that the students have a coherent understanding of the Safe-to-Fail strategies and can apply them effectively in urban design projects.

Table 2: Coefficients and P-value from Ordinal Probit regression analysis

Variables	Coeff. (β)	Std. Error	Wald	df	P-Value
Knowledge of infrastructure resilience (1 if yes, 0 otherwise)	-0.629	0.449	1.96	1	0.162
Age (1 if more than 30 years, 0 otherwise)	0.953	0.536	3.159	1	0.076
Academic Status (1 if 4 years or more, 0 less than 4 years)	1.348	0.733	3.386	1	0.066
Interest to work in infrastructure projects (1 if yes, 0 otherwise)	1.271	0.788	2.605	1	0.107
Interest to work in construction company (1 if yes, 0 otherwise)	0.494	0.39	1.605	1	0.205
Source of Safe-to-Fail knowledge (1 if Academia, 0 other wise	1.963	0.981	4.002	1	0.045
Gender (1 if Male, 0 otherwise)	-0.212	0.429	0.246	1	0.62
Current work status (1 if yes, 0 otherwise)	0.086	0.398	0.046	1	0.83
Professional experience(1 if more than 10 years, 0 otherwise)	0.116	0.916	0.016	1	0.899
Student Status (1 if International, 0 otherwise)	-0.436	0.633	0.474	1	0.491
$\boldsymbol{\mu}1$	-1.886	0.712	7.018	1	0.008
$\boldsymbol{\mu}2$	-1.239	0.667	3.454	1	0.063
$\boldsymbol{\mu}3$	0.309	0.643	0.231	1	0.631

For further insight into students' perception of the Safe-to-Fail concept, this study analyzed the students' responses for the reasons of interest to learn the concept. Figure 2 presents the reasons of interest which highlight that majority of the students agreed about stakeholders having a proper understanding of the emerging methods and design strategies such as Safe-to-Fail to resolve engineering problems effectively. Four students wanted to pursue their careers in disaster management and asserted that learning the Safe-to-Fail concept can improve their knowledge of infrastructure resilience which is critical for disaster mitigation. The remaining few students either never heard of the concept or are not interested to learn Safe-to-Fail. These students might require additional learning pedagogies that can foster their understanding of infrastructure resilience and how Safe-to-Fail strategies can help achieve such resilience. Thus, integrating Safe-to-Fail in the AEC curricula can cultivate disaster resilience knowledge and facilitate adopting and implementing this emerging design method in the real world effectively.

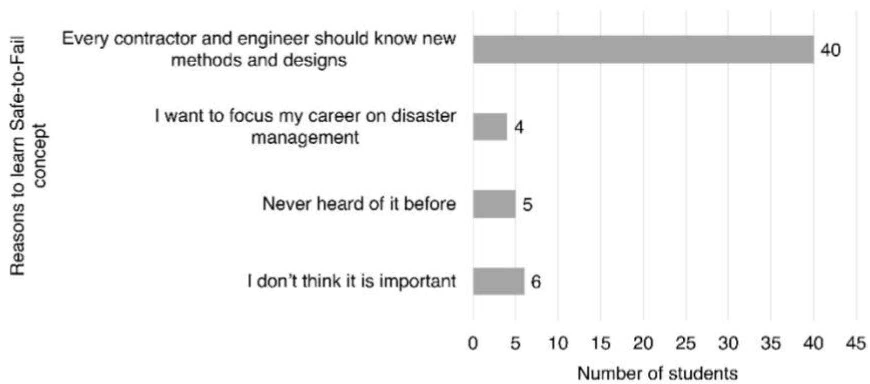

Figure 2: Reasons for interest to learn Safe-to-Fail, n=55

The study investigated the potential pedagogical approaches to integrate the Safe-to-Fail concept in the AEC curricula. Therefore, the survey included questions focusing on: (a) the likelihood of the participants to recommend incorporating Safe-to-Fail in the AEC program; (b) integrating the Safe-to-Fail concept as a core or elective course in the existing curricula; (c) integrating the Safe-to-Fail concept as a complete or portion of a course. Figure 3(a) demonstrates that 82% of the participants were likely to recommend this course to incorporate into the curricula. This indicates that the implemented framework helped the students to understand the significance of such disaster damage mitigation strategies which can also improve the AEC students' disaster management competencies in the professional world. Figure 3(b) indicates that almost 55% of the participating students preferred learning Safe-to-Fail as an elective course and 40% recommended incorporating it as a core course in the AEC curricula. Furthermore, Figure 3(c) highlights that 64% of the students suggested introducing Safe-to-Fail as a portion of a course in the AEC curricula whereas 31% of the students supported learning the concept as a complete course. These statistics provide valuable insight that can support the decision-makers to develop an innovative pedagogical approach for integrating the resilient Safe-to-Fail concept in the AEC curricula.

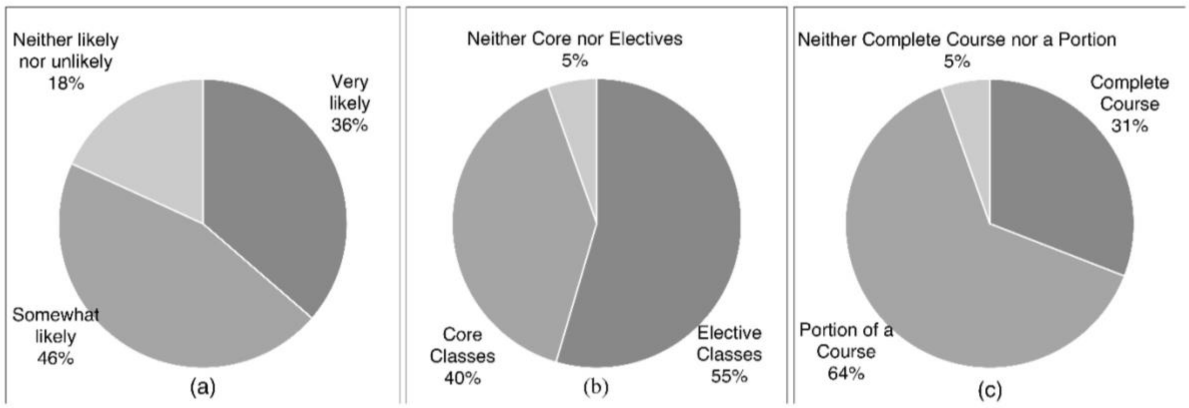

Figure 3: (a) Students' likelihood to recommend Safe-to-Fail; (b) Preference for elective course/core course/none; (c) Preference for complete course/portion of a course/none

This study focused on familiarizing the Architecture/ Engineering/ Construction (AEC) minority students who are enrolled in an interdisciplinary construction course with the resilient design concept Safe-to-Fail and stimulating their interest to learn and apply infrastructure resilience in their professional career. According to Kuh, George D. et al., (2010), student engagement such as interest in and commitment to learning is vital for success in higher education. To this end, the survey responses provided valuable insights into the innovative pedagogic design for Safe-to-Fail in the AEC curricula, that can contribute to developing a resilient built environment as well as manifest our future minority students' skills and knowledge to be better prepared for the competitive architecture, engineering and construction industries.

Another originality of this research encompasses integrating and educating emerging and cost effective resilient Safe-to-Fail strategy to the future minority workforces as well as capture their perception of learning such concepts through their curricula. This research adds to the current knowledge base by highlighting the factors that influence minority AEC students' interest to learn the resilient Safe-to-Fail design concept as well as suggesting a potential pedagogic approach that can aid academia to design sustainability and resilience in higher education, thereby improving their knowledge and skills about emerging effective design concepts and helping them contribute to build resilient built environment. Such knowledge can develop their expertise in sustainability and resilience as well as provide them an edge for the competitive engineering professions.

Limitation and future studies

The authors acknowledge some limitations of this research. The survey responses might be subject to biases. Moreover, the study has a low value of R^2 indicating that other variables may influence students' interest to learn Safe-to-Fail which have not been considered in this study. However, this study intends to analyze the particular relationships of the variables that are considered in this study thus the low R^2 value does not affect the results [24]. Some of the additional assessments for future studies can focus on (1) utilizing different learning methods to assess the optimal approach for teaching the Safe-to-Fail concept which maximizes students' knowledge retention and facilitate them to contribute to mitigating the impact of natural disasters; (2) implementing an intervention in an interdisciplinary environment and capture students' perceptions towards learning Safe-to-Fail as well as assess their interest for involvement and engagement in Safe to Fail projects; and (3) to assess if a different framework yields a different result, other studies may propose and implement a different framework and conduct an analogy to compare the results of this study.

Conclusion

This paper introduces the disaster-resilient technique, Safe-to-Fail to the Architecture/ Engineering/ Construction (AEC) students and captures their perceptions regarding learning such innovative resilient design strategies. The emerging Safe-to-Fail concept emphasizes strategies that are critical in restoring natural patterns and processes in the coastal region to reduce intense flooding. This research evaluates the significant factors that influence students' interest to learn such new and innovative strategies by implementing a comprehensive framework in an interdisciplinary Sustainable Approach to Construction course under a construction management program. The course had a uniform enrollment of architecture, engineering, and construction students at an educational institution located in a disaster-prone area. The framework included a comprehensive lecture followed by an interactive discussion session and a questionnaire survey to capture the students' insights regarding the Safe-to-Fail concept and its integration into the curricula. The results obtained from the Ordinal Probit regression model indicated that the students' age, length of time spent in the program, and source from where they learned about Safe-to-Fail knowledge significantly influences their interest to learn the Safe-to-Fail concept. Moreover, most of the minority students supported integrating the Safe-to-Fail concept as a portion of a course and preferably integrated into an elective course. Thus, the novelty of this research adds to the current knowledge base by highlighting the factors that influence AEC students' interest to learn the resilient Safe-to-Fail design concept as well as suggesting a potential pedagogic approach that can aid academia to design sustainability and resilience in higher education, thereby improving their knowledge and skills about emerging effective design concepts and providing them an edge for the competitive engineering professions.

References

[1] CRED, "Natural disasters 2019," 2019.

[2] A. C. Aparicio and A. M. Ruiz-teran, "Tradition and Innovation in Teaching Structural Design in Civil Engineering," vol. 133, no. October, pp. 340–349, 2007, doi: 10.1061/(ASCE)1052-3928(2007)133.

[3] Y. Kim, "Safe-To-Fail Infrastructure for Resilient Cities under Non-Stationary Climate," 2018.

[4] J. Ahern, "From fail-safe to safe-to-fail: Sustainability and resilience in the new urban world," *Landsc. Urban Plan.*, vol. 100, no. 4, pp. 341–343, 2011, doi: 10.1016/j.landurbplan.2011.02.021.

[5] J. Ahern, "Urban landscape sustainability and resilience: The promise and challenges of integrating ecology with urban planning and design," *Landsc. Ecol.*, vol. 28, no. 6, pp. 1203–1212, 2013, doi: 10.1007/s10980-012-9799-z.

[6] Y. Kim, D. A. Eisenberg, E. N. Bondank, M. V. Chester, G. Mascaro, and B. S. Underwood, “Fail-safe and safe-to-fail adaptation: decision-making for urban flooding under climate change,” *Clim. Change*, vol. 145, no. 3–4, pp. 397–412, 2017, doi: 10.1007/s10584-017-2090-1.
[7] J. Park, T. P. Seager, P. S. C. Rao, M. Convertino, and I. Linkov, “Integrating risk and resilience approaches to catastrophe management in engineering systems,” *Risk Anal.*, vol. 33, no. 3, pp. 356–367, 2013, doi: 10.1111/j.1539-6924.2012.01885.x.
[8] A. Al Rasbi *et al.*, “Safe-to-Fail Adaptation Strategies for Phoenix-area Roadways Under Increasing Precipitation,” 2016.
[9] Carol Considine and Emily Steinhilber, “COLLABORATIVE STRATEGIES FOR SEA LEVEL RISE ADAPTATION IN HAMPTON ROADS, VIRGINIA,” 2018, doi: https://doi.org/10.3992/1943-4618.13.3.193.
[10] B. Paolo, F. D. M., U. Thomas, and Z. Tim, “Resilience and Sustainability of Civil Infrastructure: Toward a Unified Approach,” *J. Infrastruct. Syst.*, vol. 20, no. 2, p. 04014004, Jun. 2014, doi: 10.1061/(ASCE)IS.1943-555X.0000177.
[11] NAAB, “NAAB Conditions for Accreditation,” p. 15, 2020.
[12] ABET, “CRITERIA FOR ACCREDITING ENGINEERING PROGRAMS, 2020-2021,” 2019.
[13] ACCE, “STANDARDS AND CRITERIA FOR ACCREDITATION WITH COMMENTARY.” American Council for Construction Education, 2021. [Online]. Available: https://33d9a470-25f9-40dd-962f-fd51c9953648.filesusr.com/ugd/683b8d_9eb50382e2ae479d9e1b624ecf0f22b5.pdf
[14] N. Salzman, B. C. S. Chittoori, S. M. Miller, and T. A. Robbins, “Senior Civil Engineering Students ’ Views on Sustainability and Resiliency,” 2018.
[15] R. J. Milcarek, M. J. Garrett, R. L. Falkenstein-smith, and J. Ahn, “The Development and Evolution of the Engineering Design Process in Engineering Education : From Sustainability towards Resilience,” 2020.
[16] ASCE, “Achieving the Vision for Civil Engineering in 2025: A Roadmap for the Profession,” 2009. doi: 10.1061/9780784478868.002.
[17] M. H. Finewood and J. A. Henderson, “What higher education can bring to resilience: reports from Pace University’s water resilience conference,” *J. Environ. Stud. Sci.*, vol. 9, no. 3, pp. 316–321, Sep. 2019, doi: 10.1007/s13412-019-00557-w.
[18] C. Lopez del Puerto, H. Cavallin, J. Perdomo, J. Munoz Barreto, O. Suarez, and F. Andrade, “Developing a Collaborative Undergraduate STEM Program in Resilient and Sustainable Infrastructure,” in *2019 ASEE Annual Conference & Exposition Proceedings*, Tampa, Florida, Jun. 2019, p. 32629. doi: 10.18260/1-2--32629.
[19] I. Pagán-Trinidad, R. Lopez, and E. Diaz, “Education and Building Capacity for Improving Resilience of Coastal Infrastructure,” in *2019 ASEE Annual Conference & Exposition Proceedings*, Tampa, Florida, Jun. 2019, p. 32686. doi: 10.18260/1-2--32686.
[20] N. Salzman, B. Chittoori, S. Miller, and T. Robbins, “Senior Civil Engineering Students’ Views on Sustainability and Resiliency,” in *2018 ASEE Annual Conference & Exposition Proceedings*, Salt Lake City, Utah, Jun. 2018, p. 30957. doi: 10.18260/1-2--30957.
[21] M. Elzomor, P. Pradhananga, G. Santi, and S. Vassigh, “Preparing the Future Workforce of Architecture , Engineering , and Construction for Robotic Automation Processes,” 2020.
[22] P. Pradhananga, M. ElZomor, G. Santi, and A. M. Sadri, “Integrative Pedagogical Framework to Support Construction Students’ Professional Skills and Engagement,” in

2020 ASEE Virtual Annual Conference Content Access Proceedings, Virtual On line, Jun. 2020, p. 34856. doi: 10.18260/1-2--34856.
[23] Kuh, George D., Kinzie, Jillian, Schuh, John H., and Whitt, Elizabeth J., *Student Success in College: Creating Conditions That Matter*. John Wiley & Sons, 2011, 2010.
[24] F. Moksony, "Small Is Beautiful : The Use and Interpretation of R2 in Social Research," *Szociol. Szle.*, no. December, 1999.