Board 324: Intelligently Preparing the Future Construction Engineering Workforce by Connecting the Professional and Educational Communities

Dr. Homero Murzi, Virginia Tech

Dr. Homero Murzi (he/él/his) is an Associate Professor in the Department of Engineering Education at Virginia Tech. Homero is the leader of the Engineering Competencies, Learning, and Inclusive Practices for Success (ECLIPS) Lab where he leads a team focused on doing research on contemporary, culturally relevant, and inclusive pedagogical practices, emotions in engineering, competency development, and understanding the experiences of traditionally marginalized engineering students from an asset-based perspective. Homero's goal is to develop engineering education practices that value the capital that traditionally marginalized students, bring into the field, and to train graduate students and faculty members with the tool to promote effective and inclusive learning environments and mentorship practices. Homero has been recognized as a Diggs Teaching Scholar, a Graduate Academy for Teaching Excellence Fellow, a Global Perspectives Fellow, a Diversity Scholar, a Fulbright Scholar, a recipient of the NSF CAREER award, and was inducted into the Bouchet Honor Society. Homero serves as the American Society for Engineering Education (ASEE) Chair for the Commission on Diversity, Equity, and Inclusion (CDEI), the Program Chair for the ASEE Faculty Development Division, and the Vice Chair for the Research in Engineering Education Network (REEN).

Andres Nieto Leal
Anthony Olukayode Yusuf, Virginia Tech
Dr. Abiola Akanmu, Virginia Tech
Sheryl Ball
Dr. Andrea Nana Ofori-Boadu, North Carolina A&T State University

Dr. Andrea N. Ofori-Boadu is an Associate Professor of Construction Science and Management with the Department of Built Environment within the College of Science and Technology at North Carolina Agricultural and Technical State University (NCA & T). Her research interests are in partial cement replacement materials, delivery of sustainable built environments, and professional identity development in STEM students, particularly architecture, engineering and construction (AEC) women.

In February 2019, Andrea received the prestigious National Science Foundation NSF - CAREER award to research professional identity development processes in undergraduate AEC women. She also received an NSF - RAPID award in 2020 to investigate decision making processes in STEM students during the COVID-19 pandemic. Dr. Ofori-Boadu has also received grants from East Coast Construction Services, Engineering Information Foundation, National Association of Home Builders, National Housing Endowment, University of North Carolina, and the Department of Education.

In 2021, Dr. Ofori-Boadu was selected as one of six female faculty to be highlighted in the Center of Product Design and Advanced Manufacturing (CEPDAM) video during Women's History Month. She was also recognized as a 2021 College of Science and Technology STEMinist. Andrea also served as an NSF HBCU-UP Distinguished Panelist at NSF's 30th anniversary celebration of broadening participation. She received the 2020 Outstanding Educator award from the National Association of Home Builders and the 2020 Junior Faculty Teaching Excellence Award at North Carolina Agricultural and Technical State University. In 2019, Andrea received the Outstanding Young Investigator award for both North Carolina A & T State University and the College of Science and Technology. In 2018, she was selected as a 2018 National Science Foundation - NC A & T ADVANCE IT Faculty Scholar. She also received the 2018 CoST Teaching Excellence Merit Award. Dr. Ofori-Boadu received both the 2017 NC A & T - CoST Rookie Research Excellence Award and the 2017 North Carolina A & T State University (NCAT) Rookie Research Excellence Award. Under her mentorship, Dr. Ofori-Boadu's students have presented research posters at various NCAT Undergraduate Research Symposia resulting in her receiving a 2017 Certificate of Recognition for Undergraduate Research Mentoring. In 2016, her publication was recognized by the Built Environment Project and Asset Management Journal as the 2016 Highly Commended Paper. Andrea

has served as a reviewer for the National Science Foundation (NSF), Environmental Protection Agency (EPA), and several journals and conferences.

Dr. Ofori-Boadu engages in professional communities to include the American Society for Engineering Education (ASEE), the National Association of Home Builders (NAHB), and the National Association of Women in Construction (NAWIC).

In 2015, Dr. Ofori-Boadu established her STEAM ACTIVATED! program for middle-school girls. She also serves as the Executive Vice-President of Penuel Consult, Incorporated. She is married to Victor Ofori-Boadu and they are blessed with three wonderful children.

Intelligently Preparing the Future Construction Engineering Workforce by Connecting the Professional and Educational Communities

Abstract

The purpose of this project is to investigate the development of a framework for Connecting the Professional and Educational Communities (ConPEC). This aims to improve the accessibility of construction industry practitioners to instructors and ensure more significant interaction of students with their communities of practice (COP). The project will determine users' learning-driven preferences and develop many-to-many matching algorithms. Users will evaluate the ConPEC platform, and the matching algorithms will be improved to ensure enhanced equitable matching. The project will investigate the ConPEC platform's influence on students' disciplined perception and professional identity development. Substantive theories would be developed to explain how improved accessibility, enabled by the ConPEC framework, improves the disciplined perception and professional identity development of construction engineering students.

In addition to improved accessibility to construction COP, this project would contribute to the diversity of the nation's construction workforce and strengthen diverse forms of industry-academia interactions. Also, the platform, developed theories, and algorithms can be adapted by high schools, community colleges, and researchers to develop other technological solutions to enhance the development of students in various disciplines. The deployment of ConPEC will also produce diverse datasets for engineering education researchers, institutions, and policymakers. These data include concentration areas, current and future directions of the industry, and the extent to which institutions are preparing students to meet the demands of the industry. ConPEC will also facilitate industries' supply chain through apprenticeship programs and talent pipelines that are currently fragmented.

Introduction

Engineering programs struggle to balance exposing students to understanding the practical application of the theoretical knowledge imparted in engineering courses. Research suggests a mismatch between the skill demands of industry and the offerings of educational institutions resulting in a skill gap [1-6]. As a major contributor to the United States economy and the second-largest labor sector with 8% of the total workforce Field [7]), the construction industry is taking a massive hit from this skill deficiency. Many scholarly publications and reports regarding employability in the construction industry have reported employers' concerns and dissatisfaction with the low level of skills of their newly hired construction graduates [8-13]. As expressed by many employers, one of the downstream implications of these skill gaps is project failure due to decreased work performance, productivity, and efficiency.

One way of reducing skills gaps is by connecting learners with their communities of practice (CoP) (i.e., industry practitioners) so that they can be inducted into expert ways of knowing, thinking, and reasoning. Researchers have argued that as learners increasingly interact with their CoP, their perceptions (i.e., ability to notice and become aware) of the composites of the profession are guided and coordinated in the ways of the practice of the profession [14-16], and they begin to identify with the profession [17-21]. In construction engineering education, meaningful participation can be facilitated by synergistically networking construction engineering programs with their CoP (i.e., the construction industry practitioners) so that instructors can have access to industry practitioners with the appropriate expertise to meet their practical course-support needs (e.g., site visits, guest lectures, and mentors for capstone projects). Researchers [20,21,22] have also argued that knowledge is distributed among people and their CoP and that learning occurs by connecting with the CoP to aggregate information from the community and participate in meaningful activities with the community.

Despite the perceived benefits of integrating academia and practice, the education community still experiences marginal and unequal access to the CoP. Access is usually achieved via one-on-one contacts and relationships, leaving institutions or instructors, and consequentially students, without such connections or relationship opportunities disadvantaged. This often contributes to the disparate levels of skill observed amongst graduating engineers, resulting in inequality in employment opportunities.

Advances in computing techniques (e.g., machine learning and game theories) are pioneering a new era of connecting, networking, and facilitating interactions between communities. A collaborative network of industry practitioners and instructors facilitated by the aforementioned techniques can be created to (1) diagnose practice knowledge needs and gaps in construction engineering programs and (2) meet these needs by providing equitable access to practitioners in the construction industry. Specifically, by using the collaborative network (called ConPEC), instructors can post their practical course-support needs and industry practitioners can post their offerings (e.g., specialization(s), ongoing innovative projects, type of support, and availability), and the instructors will be intelligently matched with industry practitioners who can meet their needs. We hypothesize that by intelligently matching the practice needs of students (and instructors) with the potential offerings of industry practitioners, students' noticing and awareness can be disciplined in the practice of construction engineering, and they can begin to identify with the construction CoP. The key question to be addressed in this research is: How does the accessibility, facilitated by ConPEC, translate into improved disciplined perception and strengthen professional identity development in construction engineering students? To address this research question, our NSF-funded project uses a mixed-methods research approach and computational analytics to make theoretical, methodological, and technological advances.

In this paper, we report preliminary results of this work to date and provide an overview of some of the findings from the data collection during phase 1 of the project.

Overall Project Aims

As mentioned, this paper reports preliminary results of the initial phase of a larger project. Therefore, we considered it relevant to present our overarching project aims so readers are familiar with the project's long-term goal. Furthermore, our work will help us understand the nature of interactions between construction engineering instructors and the CoP and how such interaction can improve students' preparation for the workplace. The research team aims to:

- <u>Aim 1.</u> Investigate the practical course-support needs of construction engineering instructors and the offerings of the construction CoP to address those needs. (**RQ1**)

- Aim 2. Develop a learning-driven matching algorithm that combines machine learning and matching theory to learn users' (instructor and industry practitioners) needs, requirements, offerings, and preferences to support optimal and equitable matching of construction engineering instructors and industry practitioners. (**RQ2**)
- Aim 3. Evaluate our framework and develop theories to explain how improved accessibility, enabled by our framework, improves construction engineering students' disciplined perception. (**RQ3**)
- Aim 4. Develop substantive theories to explain how and why our framework strengthens professional identity development in construction engineering students. (**RQ4**)

Similarly, the research questions being addressed are:

- RQ1: What are the practical course-support needs of construction engineering instructors, and what offerings from industry practitioners can meet those needs?
- RQ2: How do we leverage machine learning and matching theory to design and evaluate m**atching** algorithms that can learn the course-support needs, requirements, offerings, and preferences (of instructors and practitioners) and optimally and equitably pair of construction engineering instructors with industry practitioners?
- RQ3: In what ways and to what extent does improved accessibility to the CoP improve students' disciplined perception?
- RQ4: To what extent does improved accessibility to the CoP influence professional identity development in construction engineering students?

Our ConPEC Proposed Framework

The proposed ConPEC framework aims to improve the construction CoP's participation in the "skilling" of the future construction engineering workforce by enhancing communication and coordination with construction engineering instructors. The framework will be enabled by a software system comprising of two major parts: the frontend and the backend. As shown in Figure 1, the frontend includes apps that are installable on servers, laptops, tablets, and/or smartphones. Users can use these apps to register as course instructors or industry practitioners.

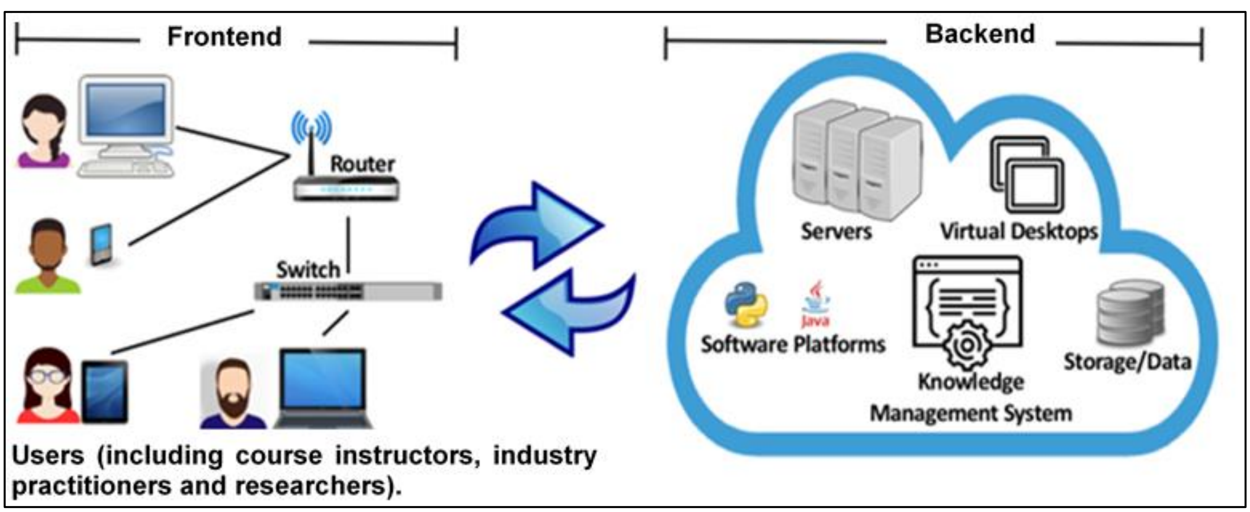

Figure 1. Overview of Proposed ConPEC framework.

Depending on the registered roles, users are presented with distinct views to interact in the following ways: An instructor can post a new course-support need and requirement, edit or remove an existing post, actively search for any potential industry practitioner, rate guest speakers, or receive any recommendation from the system on potential matches. Similarly, an industry practitioner can post their expertise, project types, availability, and instruction delivery type, respond to the requirements posted by instructors, select preferences (e.g., institutions and programs), upload videos of previous lectures, and research needs. Cross-disciplinary researchers also can log into the framework to access user input data.

The backend records all interactions between users and our system, manages the information the instructors and industry practitioners contributed, recommends potential matches between instructors and practitioners as needed, and responds to all users' data requests. The backend includes our knowledge management system, which is built on servers, software platforms, and database systems. With these elements, ConPEC leverages game theories and machine-learning techniques to analyze users' behavioral patterns, characterize stored data, recommend matches, and optimize those recommendations on the fly. Meanwhile, ConPEC implements off-the-shelf security mechanisms to authenticate and authorize users, secure data communications, and encrypt stored data. Researchers could filter the stored data to obtain the following: dynamic industry skill demands, extent to which construction programs are meeting skill demands, and diversity in educational institution response to industry skill demands. These data would be valuable to engineering education researchers to address the changing skills gaps in the construction industry. As a proof of concept, a preliminary version of ConPEC has been created to pair instructors with industry practitioners based on the areas of specialization of the industry practitioners. The preliminary ConPEC is built on a cloud platform that accommodates a large pool of computing, storage, and network resources.

Theoretical frameworks

The proposed research will be conducted through two lenses: disciplined perception [23] and identity development [23, 24]. Disciplinary perception will help uncover how students develop skills and competencies by interacting with their CoP, and identity development will help us understand how and why students come to recognize themselves as professionals.

Disciplined Perception

Drawing from Goodwin's work on professional vision [25], Stevens and Hall [24] asserted that professionals have unique ways of noticing their work that are characteristic of their disciplines and that disciplined perception occurs when professionals engage in actions in a coordinated way over an extended period of time [26]. In other words, professionals in the same discipline share a disciplined perception, if they have "developed a noticing practice in which aspects across views can be coordinated to accomplish the tasks at hand" (p. 128). Steven and Hall further opined that learners could develop 'disciplined perception' when they interact with members of their profession or CoP so that their attention is focused on or guided to components of practice. This view is also supported by Wenger [27] who views knowledge "as distributed among people and the communities of which they are a part" and that learning is achieved through meaningful participation in the CoP. In addition to acknowledging where knowledge is generated from, Trevelyan [28] argues that engineering knowing requires harnessing knowledge, expertise, and skills that are spread across people within the CoP [29, 30]. Supporting this notion, Duke, Harper [31] asserts that learning can be achieved by aggregating and connecting information from the CoP. For engineers, learning involves acquiring disciplinary knowledge to allow the future workforce to participate in their CoP [32]. Stevens and Hall's account of engineers' disciplined perception analyzed interactions in which different ways of seeing what representations were saying between collaborating engineers working together provided opportunities for a more experienced engineer to discipline learners' perception.

Professional Identity Development

Professional identity development (PID) is the process by which students come to think, act, and feel like professionals [33]. With foundations in psychology and sociology literature, identity theorists advocate that an understanding of PID processes leads to targeted policies and programs that improve students' persistence in various professions [34]. PID is the successful integration of personal attributes and professional training in the context of a professional community. It is an ongoing process of interpretation and re-interpretation of experiences, which allows for the strengthening and maturing of an individual through a series of processes of professional education and experiences [35-37]. Multiple factors within and outside the educational and professional environment impact an individual's professional identity's evolution and progression[38]. Researchers have examined how students view themselves as participants in various STEM programs and how various constructs interact to contribute to students' PID [38-40]. Gee [39] highlights the four perspectives of identity to include: (1) nature identity; (2) institution identity; (3) discourse identity; and (4) affinity identity. Gee's model guides investigations on how students' multiple identities interact with academic and professional programs and institutional contexts as students mature and transition to think, feel, and become professionals. Helms [40] emphasizes that the beliefs, values, wants, and views of individuals regarding what they want to become influences how they interact with those structures and contexts. Cultural and social environments also influence identity development as individuals are shaped by the structures, forms, activities, and events that occur within these environments [41]. Conceptually, PID is congruent with the processes that affect the personal identity development of individuals as they progress through life and continuously organize their experiences into a meaningful whole that incorporates personal, private, public, and professional identities [42-44].

Methods

In the project's first phase, we conducted a nationwide survey focusing on understanding the information that needs to be exchanged between construction engineering instructors and the construction CoP. The goal is to identify information that can help facilitate access to industry practitioners that can complement the practical needs of construction engineering students and understand the practical course-support needs of construction engineering instructors. The survey was administered online, and 293 engineering instructors and 143 industry practitioners filled it out. In addition, we secured ethical clearance through our IRB office. Data were analyzed using descriptive statistics, and some of the responses were analyzed by different variables to see if there were any important differences to show between participants. Preliminary results of the survey are presented next.

Participants from Industry

One hundred forty-three industry practitioners filled out the survey. There are representatives from 26 states in the United States, and the majority of participants are from Virginia. It was important to understand if participants considered that their company had policies or practices to support engagement with Universities, and the majority (72%) responded yes, with 10% responding no, and 17% responding that they did not know. Similarly, we asked them if their company had a diversity, equity, and inclusion (DEI) statement, and 66% responded yes, 16% responded no, and 18% responded that they did not know. Figure 2 shows the size of the company, and Figure 3 presents the type of construction firm for the 143 participants.

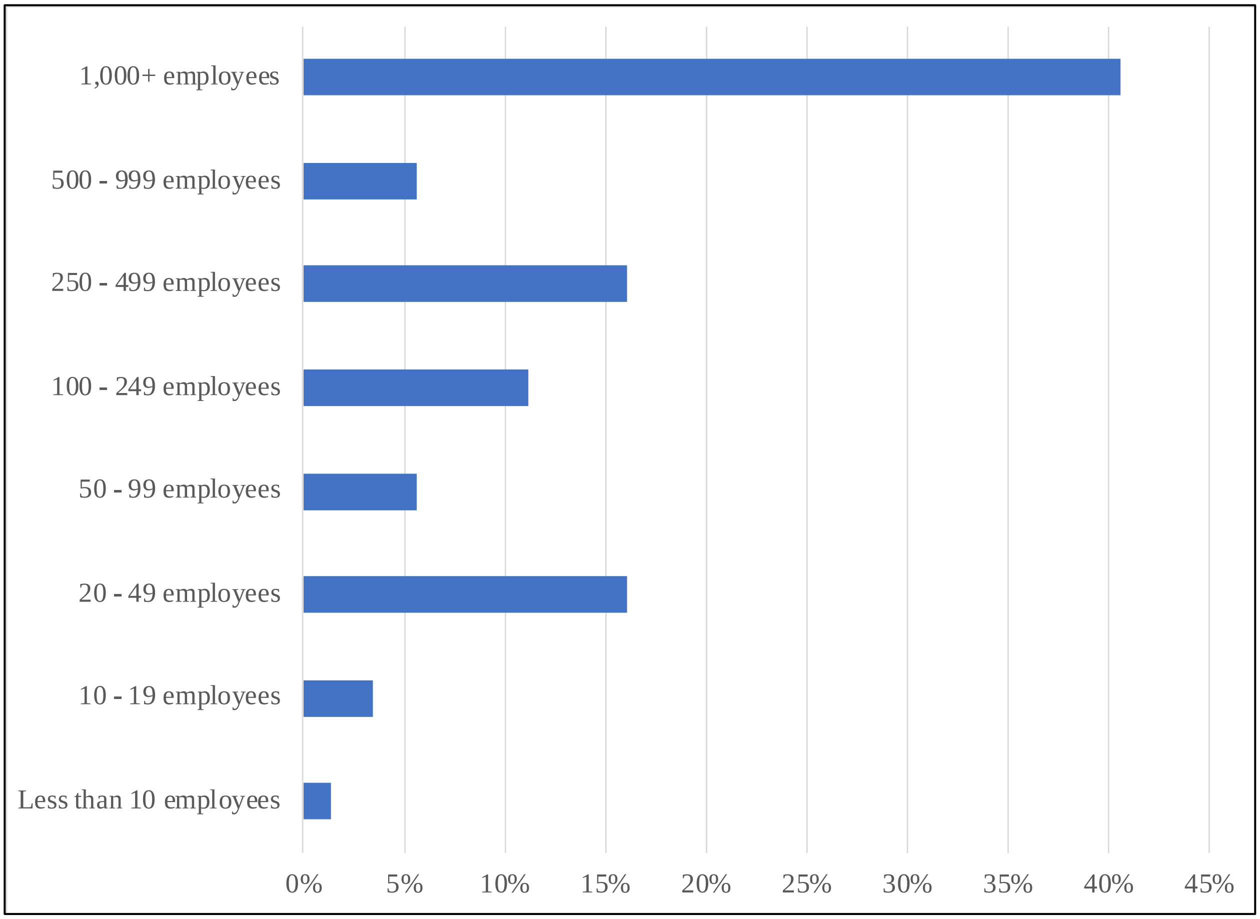

Figure 2. Size of the company

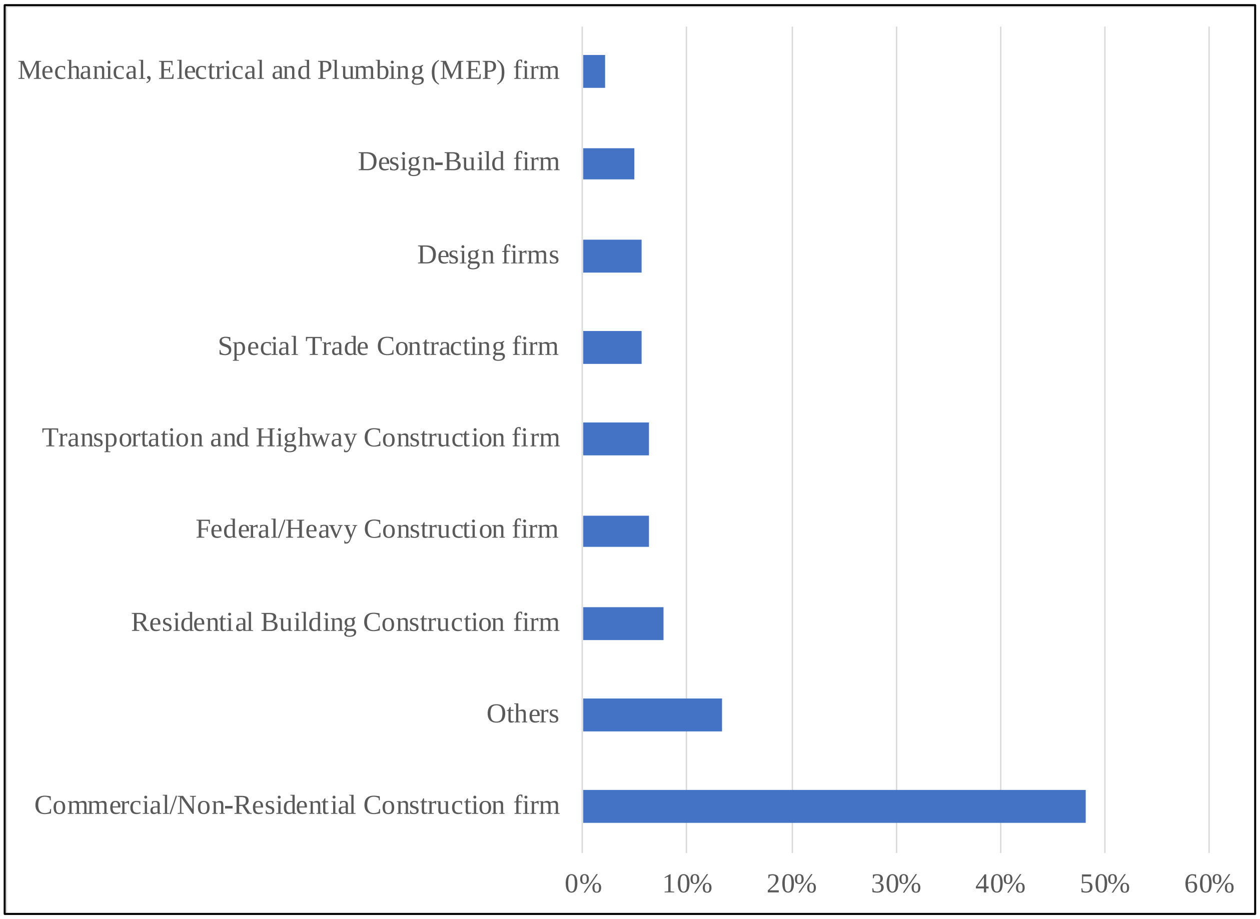

Figure 3. Type of construction firm

In terms of the demographics of the participants, table 1 presents an overview of their gender and race. Table 2 provides their age, and Figure 4 shows their years of construction industry experience.

Table 1. Industry participants' demographics

Demographics		**Number**	**Percentage**
Race	White/Caucasian	115	80%
	Asian	10	7%
	Black or African American	7	5%
	Hispanic or Latinx	6	4%
	Others	3	2%
	American Indian or Alaska Native	1	1%
	Non specified	1	1%
	Native Hawaiian or other Pacific Islander	0	0%
Gender	Male	107	75%
	Female	36	25%
	Non-binary	0	0%
	Others	0	0%

Table 2. Industry participants' age

Age range	Number	Percentage
18 - 20 years	0	0%
20 - 25 years	17	12%
26 - 30 years	27	19%
31 - 35 years	21	15%
36 - 40 years	20	14%
41 - 45 years	19	13%
45 - 50 years	7	5%
51 - 55 years	9	6%
56 - 60 years	12	8%
61+ years	11	8%

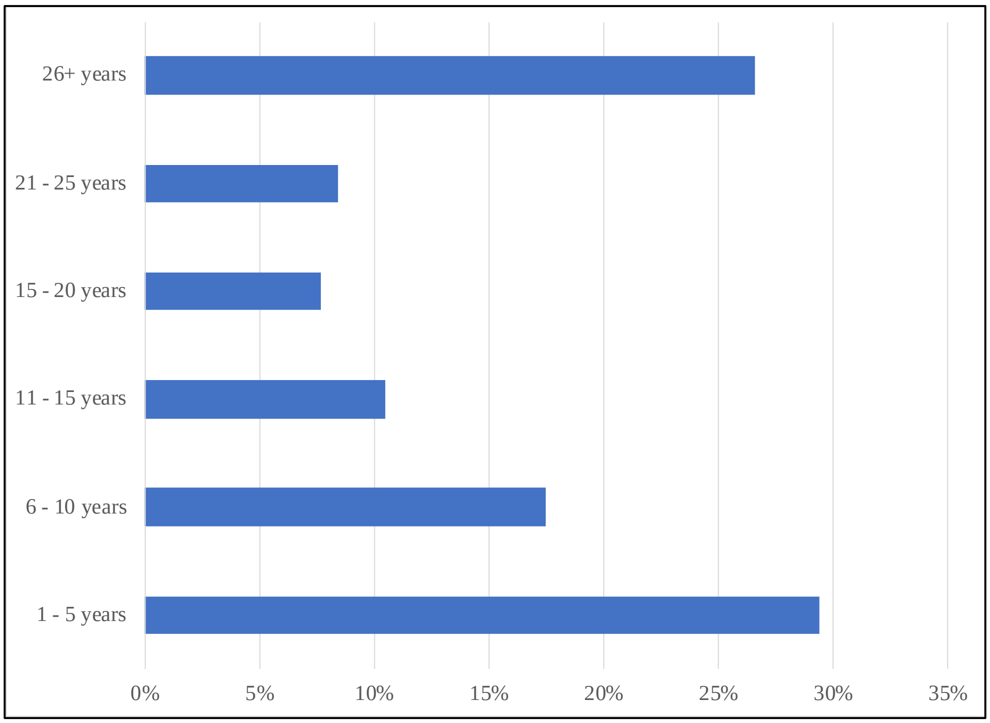

Figure 4. Industry participants' years of construction experience

Participants from Academia

Two hundred ninety-three instructors in construction engineering filled out the survey. There are representatives from every state in the United States. Table 3 presents important demographics of the participants regarding race and gender. Similarly, figure 5 presents the type of department the instructor worked for. It is important to note that 196 (66.9%) of the participants work for a predominantly White institution (PWI), 12 participants (4.1%) work for a Historically Black Institution, 44 (15%) work for a Hispanic Serving Institution, and 41 (14%) participants work for a different type of institution (other).

Table 3. Academic participants' demographics

Demographics		Number	Percentage
Race	American Indian or Alaska Native	1	0.3%
	Asian	35	11.9%
	Black or African American	25	8.5%
	Hispanic or Latinx	20	6.8%
	Native Hawaiian or other Pacific Islander	0	0.0%
	White/Caucasian	197	67.2%
	Multiracial	4	1.4%
	Others	11	3.8%
Gender	Male	212	72.45%
	Female	78	26.6%
	Non-binary	0	0.0%
	Others	3	1.0%

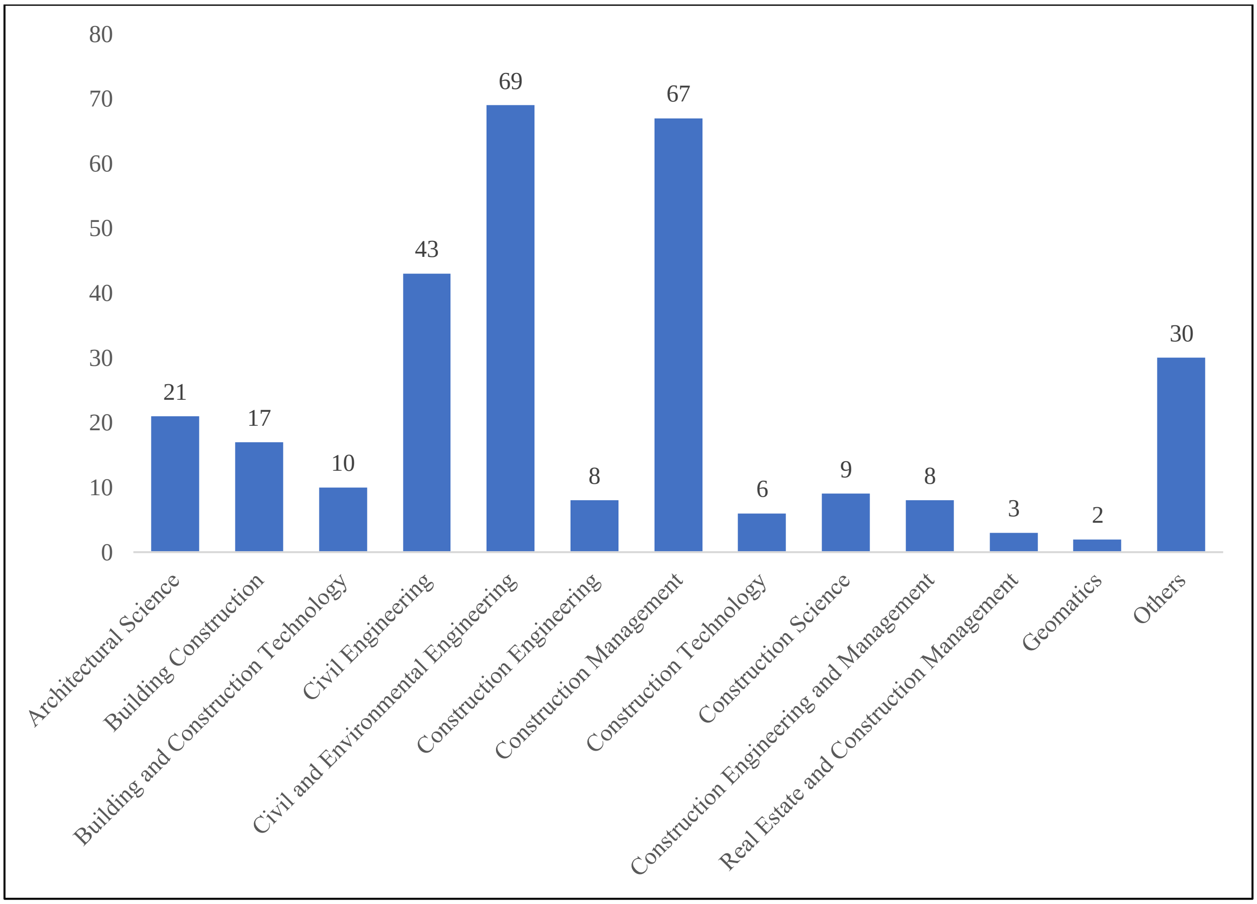

Figure 5. Academic participants' department

Preliminary Results

This initial phase helped us understand some of the perceptions that both instructors and industry practitioners had regarding the important factors to consider when making the ConPEC network. Besides presenting details about our participants, we also wanted to understand how the attributes they consider important, vary between the two groups but also how they varied according to some demographic characteristics. For example, figure 6 presents the importance that the different participants think years of experience have. It can be noted that both groups consider years of experience an essential factor to consider, however, it can be seen that for both participants, early career (1-5 years) and mid-career (11-15 years) are the groups that have the highest scores when asked the importance of years of experience.

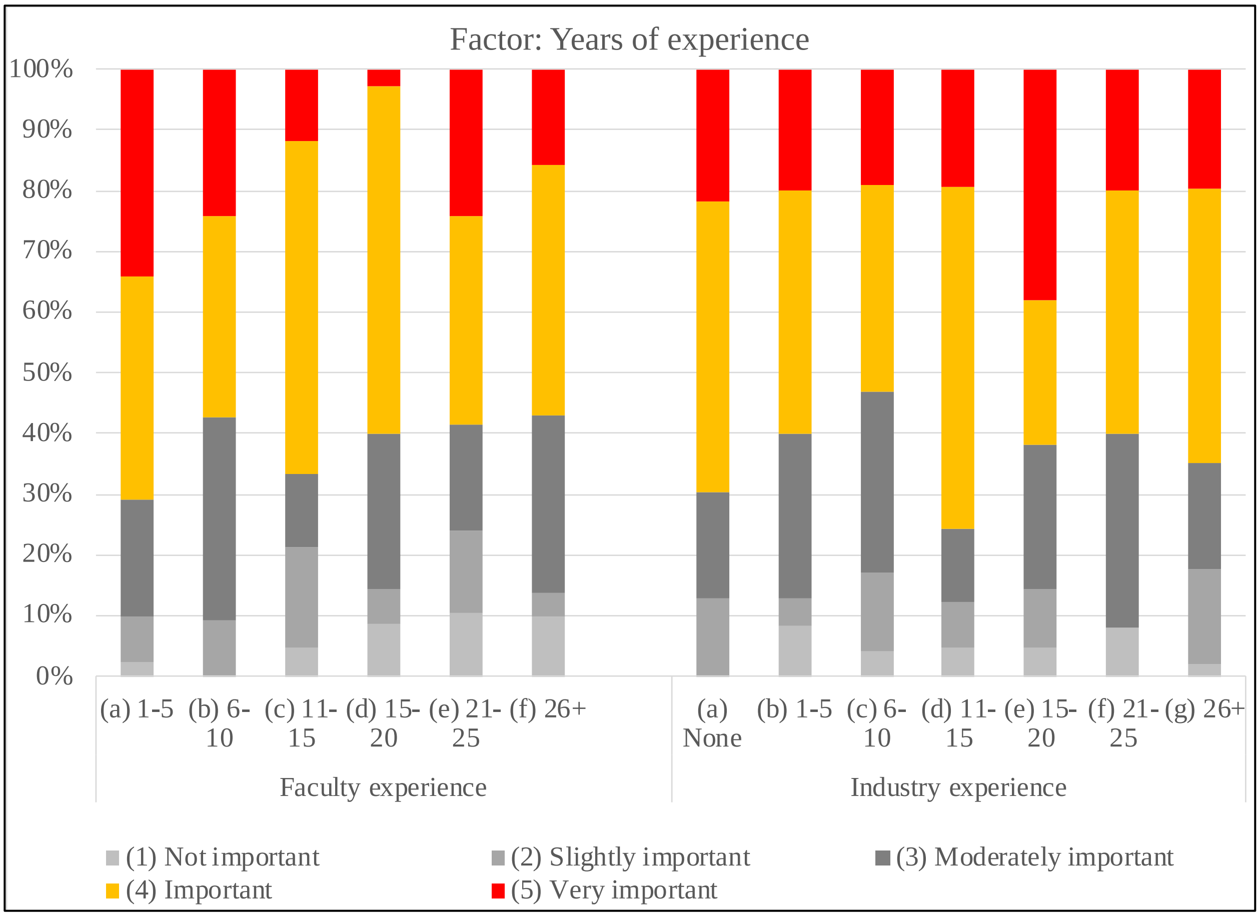

Figure 6. Importance of years of experience for industry and academia participants.

Similarly, in figure 7, when participants were asked about the importance of gender diversity in the organization, both groups agreed that the gender diversity is not that important. In both groups, it can also be seen that these factors are even less important for participants with more years of experience. In Figure 8, we present the exact data for the importance of ethnic diversity in the organization, and we can see a similar pattern as the one presented for gender diversity. We speculate that participants are focusing on technical knowledge and minimize the importance of other factors that could impact the network's development, as representation is important in mentorship and if we want to advance diversity and inclusion in engineering.

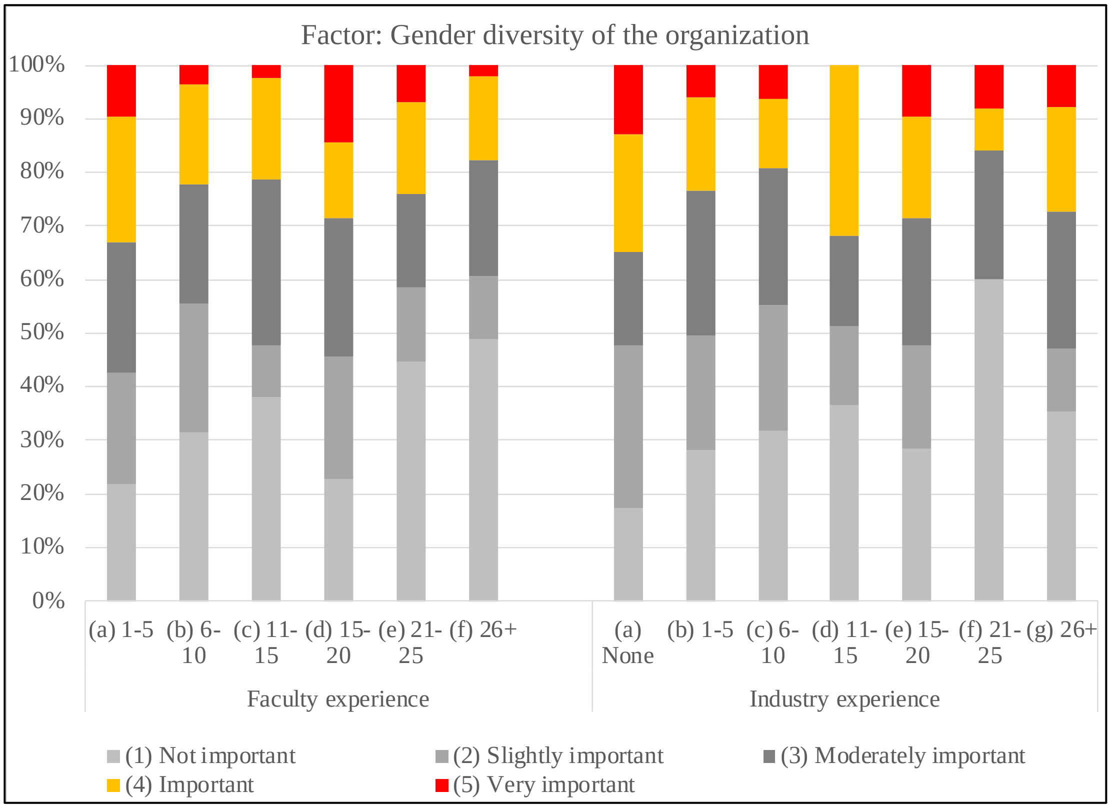

Figure 7. Importance of gender diversity for industry and academia participants.

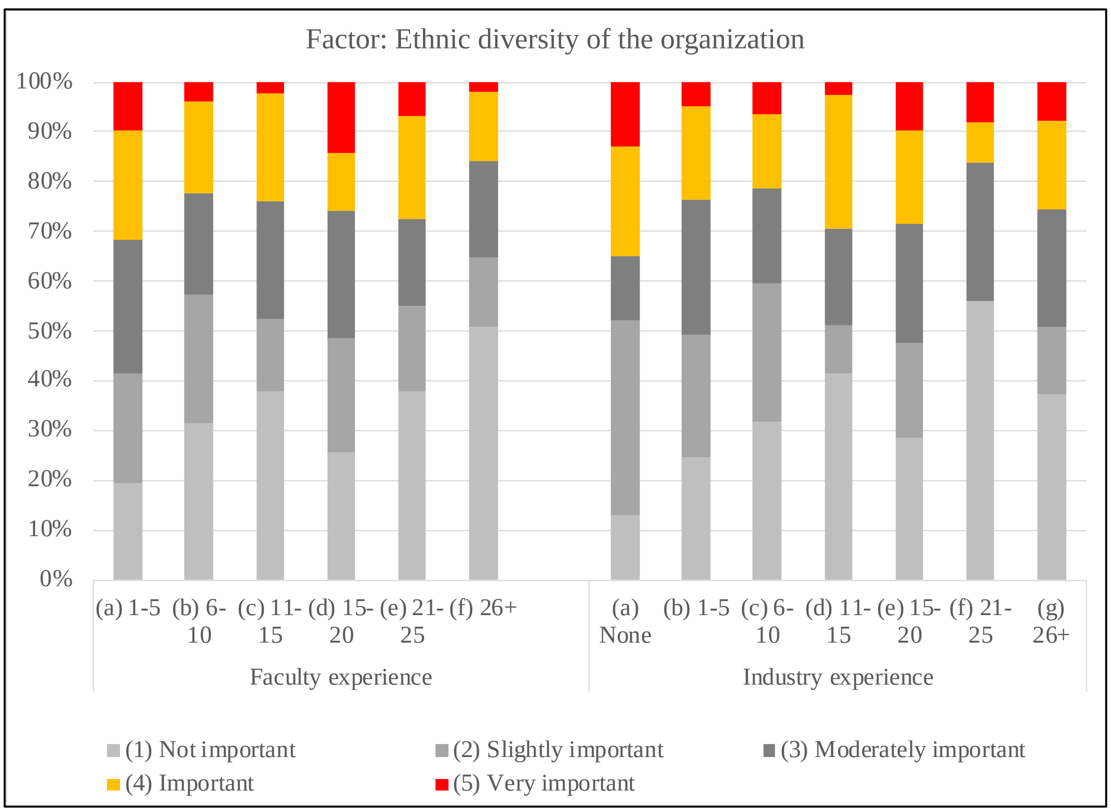

Figure 8. Importance of ethnic diversity for industry and academia participants.

Finally, in Figure 9, we can see the importance of different factors from a practitioner's perspective in terms of what is valued when making the connection to the network. For example, we can see that in terms of student-related factors, participants consider physical disabilities of the students as the most important factor, close to the safety equipment needed. These factors are important as they can make companies liable for visits. Similarly, practitioners did not find that the instructors' demographics were important factors when making the connections. Lastly, the type of academic institution was considered very important, and its location was considered less important.

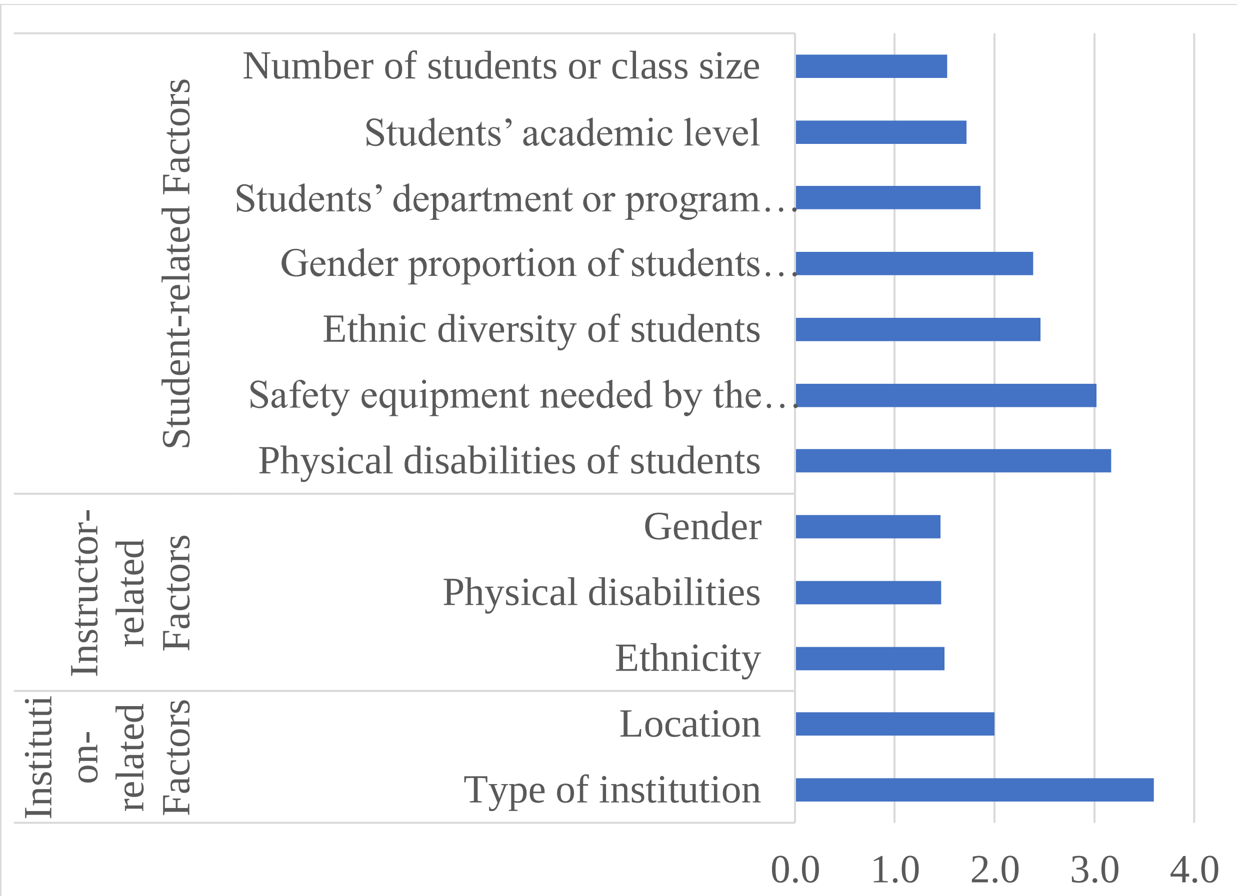

Figure 9. Importance of different factors for industry participants.

Next steps and future work

Following results from the survey, we will conduct focus groups with both industry practitioners and construction engineering instructors to explore further some of the rationale behind the importance of the different factors to be considered when creating the ConPEC platform. The survey and focus group results, including results from a user study, will inform the formalization of the proposed framework's graphical user interface (GUI) input needs, which will facilitate communication between instructors and industry practitioners. Based on instructor and industry feedback from the survey and focus groups (and the user study), we will improve and implement the preliminary version of the proposed framework that can pair instructors with industry practitioners based on the areas of specialization of the industry practitioners. Using data from the implementation, we will merge tools from machine learning and matching theory to develop novel learning-driven algorithms to pair practitioners and instructors equitably, intelligently, and dynamically. In the project's second phase, based on the algorithms, we will refine, finalize, and implement the proposed framework (ConPEC). Finally, we will deploy the completed framework nationwide so that instructors (and students) can have increased access to practitioners who can meet their practice course-support needs. We will interview and survey students, instructors, and practitioners (users of our framework and employers) to understand the influence of our framework on students' disciplined perception and professional identity development. Critical-incident interviews will allow participating students to narrate their experiences with the provisions of the proposed framework.

Acknowledgment

[Masked for review]

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