International Journal of Engineering Education Vol. 36, No. 5, pp. 1640–1651, 2020
Printed in Great Britain
0949-149X/91 $3.00+0.00

Experts' and Novices' Perspectives on the Priority of Affective Dimensions in Civil Engineering: A Mixed Methods Study*

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Although some have called for engineering curricula that fully integrates learning in the head (cognitive), hand (skill), and heart (affective) domains, others acknowledge the difficulty of overhauling existing curriculum to adequately prioritize the "heart". The opinions of experts are often consulted to inform curricular changes, but this is rarely compared to the opinions of novices. There is a need for a better understanding of both experts' and novices' perspectives on the role of the "heart" in engineering education and in engineering work. With an emphasis on civil engineering, this study uses a convergent parallel mixed methods research design and Shulman's Three Apprenticeships framework to investigate expert and novice perspectives on the priority of affective constructs in undergraduate education and their approach to designing facilities for users with needs different from their own. Data was collected from civil engineering experts and novices at an annual regional civil engineering-focused conference. Results suggest experts and novices may have different perspectives on which values should be emphasized earlier versus later in civil engineering education. Implications of the results from this study suggest that while many values should be emphasized in engineering education, it might be important for educators to emphasize certain values (e.g., compassion) earlier rather than later to assist in the development of a well-rounded engineer.

Keywords: expert vs. novice; affective dimensions; civil engineering design

1. Introduction

The results of a multi-year, multi-institutional study conducted by the Carnegie Foundation for the Advancement of Teaching [1] describe the current state of undergraduate engineering education in the U.S. and recommendations for improving it to align with the professional demands of engineering practice. In short, the authors argue that engineering programs effectively import certain types of knowledge (e.g., technical knowledge), but are not as effective at preparing students to integrate knowledge, skills, and affective elements (e.g., identity formation) as they develop into engineering professionals. This is consistent with other engineering education scholars' work on affect-related constructs.

The consequence of this approach is that engineering graduates entering the workforce struggle to transfer what they learned in school to what is required of them as a professional. The authors advocate for an innovative engineering education – a networked engineering curriculum that integrates analytical reasoning (knowledge), professional skills, and professional judgment throughout the curriculum (e.g., via design projects). This is consistent with ideas put forth by other engineering education scholars. Such an ideal would address the shortcomings of engineering education and would help align it with practice, but there are significant challenges with innovating a curriculum that corresponds to this blueprint. This type of change cannot come at once; it must be done over time. Given the difficulty of overhauling an entire curriculum, it is exciting to see the growing body of scholarship including examples that exemplify how to present a networked approach to teaching and learning in engineering education. This study also assumes the

* Accepted 1 April 2020.

value of a "networked" approach to the design of engineering learning experiences such that there is an integrated and equal emphasis on analytical reasoning, professional skills, and professional judgments while students are learning to become professionals.

Within engineering-related fields, academic preparation for the profession is primarily focused on technical knowledge; but there is a need for more integrated learning experiences that involve different kinds of knowledge (Head), skills (Hand), and professional judgment (Heart) [1]. While there have been efforts to make the integrated/networked curriculum the norm in engineering education, the linear sequence and emphasis on certain types of knowledge still prevails as the default approach [2]. While there is significant engineering education research centered on students' progression through the curriculum (e.g., first year engineering, the middle years, capstone design), there is room for more scholarship that explicitly focuses on student experiences in specific disciplines. Thus, this study adds to the contributions of engineering education researchers like Simmons [3, 4] by emphasizing the need for integrated learning experiences in civil engineering; this is the focus of this study.

Civil engineering education prepares future engineers to design, develop, and maintain facilities and components that are the most closely associated with the physical and natural environment. In the field of civil engineering, a review of the nation's top 90 schools found that the majority of courses taken (66%) were focused on engineering topics; and this majority was followed by courses on math and science (35%) and general education courses (27%) [5]. Of these schools, only three programs required a course in either leadership or team building and seventeen required a course in engineering ethics. The majority (80%) of engineering graduates were not required to take an engineering ethics course [6]. A five-year review of integrated curriculum for a civil engineering program found that communication and ethics were not taught until the junior year of students' college career [7]. This lack of emphasis and integration of non-technical content and skills has been cited as a problem in many engineering disciplines.

The authors of this study acknowledge that overhauling an entire civil engineering curriculum to achieve a more integrated result is challenging and often infeasible. Oftentimes, the opinions of experts in an area are consulted to inform the refinement process. Existing studies have compared the differences in how engineering experts and novices perform on cognitive and skill-related tasks, but no studies have performed this comparison in light of affective dimensions in engineering. With civil engineering as an example, this study focuses on comparing expert and novice perspectives on the role of affective and value-laden constructs in engineering education and design.

2. Literature Review

2.1 Comparing Experts and Novices

Research has found that experts and novices have fundamental differences in the way that they perceive and process information in the realm of their study (e.g., [8, 9]) Experts have been found to have key characteristics that differentiate them from novices of the same field. Glaser & Chi [10] wrote a comprehensive overview of expert characteristics. For example, expertise exists in specific domains and are not transferable. Thus, expert status in one field (i.e., civil engineering) may not guarantee expert status in a different field. With this specialized expertise, experts are more capable of extracting meaningful patterns from information gleaned in their specific domain of interest than novices. Specifically, experts have more complex methods of synthesizing information into chunks that are directly applicable to their field. Moreover, experts tend to complete relevant tasks faster than novices. This may be due to their overall ability or greater capacity resulting from the larger pool of information from which they draw. In addition, experts have better short and long term memory in relation to their domain of expertise than novices. Furthermore, experts are able to analyze problems in their field at a deeper level than novices [11]. For example, novices may sort issues based on their categorical attributes while experts tend to sort issues based on the method for solving the problem. Experts also tend to use qualitative information (e.g., using the context of an issue) to help solve a necessary problem rather than only focusing on how to produce numerical solutions. The ability to also assess for qualitative information allows for experts to also consider how the context of specific environments may impact the solution. Lastly, experts tend to be more self-aware of themselves than novices. Specifically, experts have better skills at noticing when they have created a mistake or how to solve their mistakes once they have been identified.

Expert and novice differences have been found in the engineering field, and more specifically in design and civil engineering. In an in-depth study of experts versus novices, in multiple engineering disciplines, found that experts tend to take more time in each phase of the design process (i.e., problem scoping) and were successful in gathering more information than novices [12]. Authors argue that their study provides evidence that experts and novices fundamentally differ in their problem scoping and information gathering processes in relation to design. Furthermore, a transdisciplinary design study found that experts in design typically use concepts such as organized translation (i.e., how to create a design that makes sense in a larger context of environment) and intentional progression (i.e., utilizing each design project as part of a larger goal) [13]. On the other hand, a study on how first-year engineering students approached design challenges found that women engineers were significantly more likely to consider context-relevant information in their designs than men [14]. Authors argues that context-relevant information is important to integrate into engineering curriculum, especially if male students struggle to integrate how to look past a technical/logistical frame of reference (i.e., dimensions) and consider social references (i.e., accessibility for the user, safety).

From these studies, there appears to be a difference in the method in which experts and novices approach design in engineering as well. Furthermore, this combination of evidence on what distinguishes an expert from a novice in general and in engineering tends to focus on cognitive and skill-based differences, but still highlight technical and non-technical characteristics. Considering the importance of the head (cognitive), hand (skills), and heart (values) in engineering practice, in general, and civil engineering in particular, there is a need to understand the difference between how experts and novices prioritize these specific values in their work. Such insights would be helpful for preparing civil engineering students to pursue careers that require comprehensive expertise.

2.2 Theoretical Framework: The Three Apprenticeships

The Three Apprenticeships approach appears to begin with John Dewey, a professor and researcher of education, who wrote that teachers not only need to be educated on theory, but also practical application [15]. Dewey argued that there were two approaches in preparing teachers for their profession: the apprenticeship approach (i.e., practical skills required for the job) and the laboratory view (i.e., integrating theory with application). Dewey postulated that the laboratory view was more scientifically-informed and would therefore be more progressive for the field of education. Lee S. Shulman went on to expand upon Dewey's theory with his own approach of three apprenticeships. Shulman theorized that professional education is composed of three apprenticeships: cognitive, practical, and moral [16]. Cognitive apprenticeships are described as education focused on instructing the student to think like a professional. Practical apprenticeships focus on educating students to perform like a professional. Lastly, moral apprenticeships focus on educating students to act in an ethical and responsible manner that incorporates both cognitive and practical skills.

Following this line of research, the Transformative Sustainable Learning (TSL) theory was created to ensure that certain values were imparted in education to ensure a sustainable future that will continue to progress our society [17]. Through case study methodologies, researchers found that three major constructs that contribute to sustainable learning were the head, hand, and heart. These constructs refer to cognitive (e.g., academic study), psychomotor (e.g., building), and affective (e.g., values and attitudes) learning domains, respectively. Sipos and colleagues [17] argue that all three of these constructs should be implemented into inter/transdisciplinary education. From this line of research, it is arguable that engineering education needs to integrate a tripartite method of education that involves knowledge, skills, and values-based curriculum.

2.3 A Focus on the "Heart"

There are a variety of constructs that fall under the Heart apprenticeship of learning such as identity, values, and attitudes. The research to this point has mainly focused on empathy as a heart related skill. Strobel, Hess, Pan, & Wachter Morris [18] conducted a three-part research study in which they examined the role of empathy in engineering. Empathy is defined by them as a multifaceted construct that generally describes one's ability to understand another's experience within their frame of reference. Although, this construct is important for engineers, especially in relation to human-centered design and communication with both team members and community stakeholders, there is limited research that reviews how engineers conceptualize empathy and integrate it into their work. Strobel and colleagues [18] extensively reviewed existing literature on empathy-related concepts and found that there were a total of 106 papers that utilized these concepts. On the whole, six terms were utilized in the literature to describe affect-related skill in engineering: humanitarian, safety, trust, user's need, compassion, solidarity, humanized, and community involvement.

Research has found how expert engineers view empathy. Strobel and colleagues [18] performed a literature review to investigate how empathy and care look within the engineering context. In addition, the authors interviewed engineering faculty to examine their views on empathy and care in engineering. From these interviews, six themes emerged. First, there is not a definitive conceptualization of empathy and how it differs from care. Second, the lack of empathy and/or care negatively impacts engineering students' ability to work with team members. Third, empathy is arguably embedded in the engineering field as its main goal is to improve society, which requires some level of empathetic understanding. Empathy allows for better instruction of students and connection with faculty. The interviews also suggested that empathy and care is indirectly taught in courses, but are not necessary to the success of students as engineers. Practicing engineers were surveyed as well and their responses were similar to the faculty. They believe that the concept of empathy is vague and not clearly defined in the field. Although there was agreement that empathy is important in relation to communication and design with stakeholders and colleagues, empathy was also viewed as a construct that unless had clear practical advantages, was not relevant to the priorities of an engineer. Overall, it seems that there is some dissenting opinions from engineering experts in terms of the importance and priority of empathy in engineering. It seems that although there is a general consensus that it is important to utilize empathy in design and communication, it still remains secondary to more technical skills.

Indeed, much of the engineering literature views empathy as a "soft" skill that is peripheral to skills that are more head and hand oriented (e.g., [19]). Although this reigning belief exists, it is clear that empathy, or heart related skills, are crucial in human-centered design and civil engineering fields. Walther and colleagues [19] proposed a method of teaching empathy skills for engineering students that requires students to switch from their responsibilities, or modes, as an engineer and harness their being (i.e., identity as a professional), orientation (i.e., values, micro to macro focus), and skill (i.e., perspective taking) in order to truly utilize empathy in their work. Although Hess and colleagues [18] found that engineering faculty believed that empathy and care were topics taught to their students, another study by Fila and Hess [20] found that engineering students had difficulty recalling instances in which empathy was taught by their instructors. The majority of these students were not taught this construct until the end of their college training and had difficulty connecting how this concept related to their work as engineers. Clearly, there appears to be a fracture between expert/faculty and student perspective of the importance and method in which empathy is taught.

One of the largest identified issues in engineering education is that communication and teamwork skills are necessary to the success of engineers, but overall these skills are lacking [21, 22]. Historically curriculum has focused mainly on technical skills without much instruction on how to integrate context-related skills (i.e., awareness of social, environmental factors) that may impact their work. Authors propose that a solution to this issue may be project based learning, which is a method of student-initiated work that mirrors working as an engineer in the field. One of the best examples of project based learning is the Engineering Projects in Community Service (EPICS) which was started after the "Engineering Criteria 2000" set guidelines for engineering education to incorporate multidisciplinary teams and to learn how to communicate effectively [23]. The goal of EPICS is for engineering students to utilize their learning and skills to benefit their community. This process is known as service learning. EPICS teams are composed of eight to twenty undergraduate students with a mixture of freshmen, sophomores, juniors, and seniors. The rationale for this is so that there can be continuity between the EPICS team and their community partnership so that after one project is done, another project can be created with some of the younger team members moving into a more expert role. In student evaluations of the EPICS program, the majority of students have cited that community service and learning "real world" application of learning was extremely helpful. In addition, the retention rate from semester to semester in the EPICS program is fairly high (approximately 77%). The students also reviewed that EPICS was able to supplement their learning and improve their ability to communicate, work in a team, and have awareness of their community and customer for engineering projects. Overall, EPICS is a prime example of how multidimensional learning can be especially meaningful for students.

For the Three Apprenticeships model to be fully implemented into engineering curriculum, it will be important to start with gauging expert engineers' opinions of the topic, specifically the espoused values of the engineering field. Edgar Shein is one of the leading minds of organizational learning [24]. He believes that organizational culture is composed of three tiers: (1) artifacts, (2) values, and (3) underlying assumptions. Artifacts are the visible markers of an organization that make them known to others; they are composed from the values and underlying assumptions of the organization. Values are the reason that the organization does what they do and the importance of those actions to the organization. Lastly, the underlying assumptions of an organization create the values and artifacts of the organization. Because underlying assumptions are implicit, it is often easier to examine artifacts and espoused values of an organization.

Table 1. Descriptive Statistics Comparing Experts and Novices (N = 37 for Novices and N = 47 for Experts)

	Expert		Novice	
Values	**Mean**	**SD**	**Mean**	**SD**
Trust	3.49	2.41	4.49	2.49
Humanized	5.98	1.85	5.24	2.47
User's Needs	4.58	2.60	5.38	2.48
Community Involvement	6.3	2.34	5.68	1.96
Solidarity	5.64	2.49	5.19	2.49
Compassion	5.62	2.60	3.24	2.18
Safety	3.26	2.55	6.19	2.63
Empathy	4.47	2.58	4.35	2.52
Humanitarian	5.74	2.07	5.24	3.00

Note: Ranking: 1 = Most important 9 = Least important.

3. Purpose, Research Questions & Design

With an emphasis on civil engineering, the purpose of this study is to investigate expert and novice perspectives on the priority of affective constructs in undergraduate education and their approach to designing facilities for users with needs different from their own.

This study uses a convergent parallel mixed methods research design to address the following research questions: *What, if any, are the differences in how civil engineering experts and novices rank which values should be prioritized in an undergraduate civil engineering curriculum? What are the similarities and differences in civil engineering expert and novice approaches to designing facilities for users with diverse needs? To what extent do the quantitative and qualitative results converge?*

4. Quantitative Strand: Results of a Heart-Focused Survey

In order to study Heart values in engineering, we examined current research that has been conducted along this line, which has mainly focused on empathy (i.e., a multifaceted construct that generally describes one's ability to understand another's experience within their frame of reference). Strobel, Hess, Pan, & Wachter Morris [18] reviewed all existing literature on empathy-related concepts in engineering and found that there were a total of 106 papers that utilized these concepts. On the whole, eight terms were utilized in the literature to describe affect-related skills in engineering: humanitarian, safety, trust, user's need, compassion, solidarity, humanized, and community involvement. To understand the current perspectives of the civil engineering field, these eight terms along with empathy were utilized to study which affect-related skills should be emphasized in civil engineering curriculum.

A Mann-Whitney U test [25] was computed to compare expert and novice groups in terms of their ranked values (i.e., which values should be emphasized earlier or later in students' education). This statistical test is appropriate for comparing groups and when the data distribution is asymmetrical (i.e., ordinal data). The Mann-Whitney U test states that the null hypothesis is accepted when the two groups have the same distribution, or come from the same population. When the alternative hypothesis is accepted, this suggests the groups are from different populations.

4.1 Results

Means and standard deviations of the experts' and novices' rankings of values are displayed in Table 1. Non-parametric statistic ChiSquare was used to compare the relative frequencies of value rankings between experts as well as between novices (e.g., primary area of impact). For novices, there was a significant difference between groups in that those who chose planning as the building and construction phase they are most interested in, ranked user's needs to be emphasized earlier on in engineering education than those that chose operations X^2 (3, N = 37) = 7.97, $p = 0.046$. There were no significant differences in rankings for novices in terms of years of work experience. For experts, there were no significant differences in rankings in terms of years of work experience, primary area of impact and current work sector. There was a trending difference in ranking of empathy for experts. Those who said that empathy should be emphasized later in engineering education also reported they work in the industry field X^2 (1, N = 48) = 3.26, $p = 0.07$.

The expert and novice groups differed in their ranking of the safety and compassion values. A Mann-Whitney U test indicated that the compassion value was ranked higher for experts (i.e., should be emphasized later in engineering education) than for novices $U = 429$, $p < 0.005$. A Mann-Whitney U test indicated that safety was ranked lower for experts (i.e., should be emphasized earlier

Table 2. Mean Ranks from the Mann-Whitney U test

	Mean Rank		
Values	**Novice**	**Expert**	**P value**
Trust	47.76	38.36	0.08
Humanized	38.82	45.39	0.22
User's Needs	45.54	38.18	0.16
Community Involvement	38.62	45.55	0.19
Solidarity	40.07	44.41	0.41
Compassion	30.59	51.87	0.00*
Safety	55.85	31.99	0.00*
Empathy	41.96	42.93	0.86
Humanitarian	40.31	44.22	0.46

* $p < 0.005$.

in engineering education) than for novices, $U = 375.5$, $p < 0.005$. Table 2 shows the mean rankings of values to highlight differences between experts and novices.

5. Qualitative Strand: Focus Groups with Civil Engineering Novices & Experts

Two focus groups, one consisting of novices and the other of experts in the same field of civil engineering were compiled to explore their approaches to designing facilities (or components) for users with diverse needs. A focus group methodology was utilized to provide an informal, comfortable setting for participants to have open discussion about their thoughts and perceptions of the research topic [26]. Focus groups have been utilized to create streamlined research questions [27]. Expert engineers were asked about their perceptions on Heart related aspects in the engineering field. Their feedback was utilized to tailor the current study's research question. Research has found that experts and novices have fundamental differences in the way that they perceive and process information in the realm of their study (e.g., [8, 9]). Experts have been found to have key characteristics that differentiate them from novices of the same field. In an in-depth study of experts versus novices in multiple engineering disciplines found that experts would take more time in each phase of design (i.e., problem scoping) and were successful in gathering more information than novices [12]. In addition, focus group methodologies allow for the collection of group interaction data which was utilized to examine group dynamics [28].

5.1 Participants

A convenience sample of expert ($n = 3$) and novice ($n = 2$) engineers were recruited for participation in this study. Novice engineers were male third-year students, from a large university in the southwest region of the United States, who were enrolled in civil and architectural engineering programs and had completed coursework on the design and development of facilities for a variety of users. The expert engineers – 2 men and 1 woman – were recruited from an industrial advisory board to the civil and architectural engineering program at a large university in the southwestern region of the United States. These expert engineers have been working in the civil engineering field for at least ten years.

5.2 Data Collection

The data for this study was collected from the principal investigator (PI) of this study via audio-recorded focus group interviews. Audio was recorded after the PI received verbal consent for permission to record from all focus group members. The PI provided participants with information regarding the purpose of the study, the voluntary nature of the study, and the ability to stop recording whenever necessary. The expert focus group was conducted in-person at a large southwestern university in the United States. The expert focus group lasted approximately 1.5 hours. The novice focus group was conducted via phone and lasted 45 minutes.

Both focus groups were semi-structured and utilized open-ended questions to generate the most amount of information from the participants. The questions in the protocol were created to garner rich information regarding the design process of expert and novice engineers when designing for users with unique needs. The 'expert' interview protocol was informed by existing literature on how experts and novices differ in their processes for acquiring knowledge and how they represent knowledge (e.g., domain-specific vs. general knowledge) [29]. The questions were geared towards a sample of professional engineers and labeled experts based on the fact that they have some work experience in the field of engineering. The initial set of interview questions were informed by the cognitive domains that experts tend to exhibit when designing an artifact for a human user. For example, in the paper by Popovic [29], they found that experts displayed domain-specific knowledge, perceived large meaningful patterns and exhibited task experience and expertise.

The interview questions were further refined in light of the Three Apprenticeships Model [1]. Taking into account the 'heart' dimension of that model, questions were revised to encourage interviewees to take on the perspective of the users for whom their designs would impact, a construct of empathy [30]. The revised interview protocol was shown to professional engineers for their feedback. They provided alternate phrasing/wording for some of the questions. For example, they suggested reflecting back on the helpful feedback they received specifically from their mentors rather than feedback in general. The final interview protocol was piloted with a sample of experts recruited from the Associated Schools of Construction (ASC) Regions 6 & 7 2018 Student Competition and Construction Management Conference in Nevada. Expert and novice participants were asked to complete an interview and set of survey questions.

During the focus group interviews, the PI facilitated the interviews. The PI was intentional with probing for all group members' opinions regarding each question. In addition, the PI would probe for further information when needed. For expert engineers, much of the information shared was tacit knowledge and required to be explained more clearly. For the novice engineers, further probing was necessary to expand upon their responses.

5.3 Data Analysis

The present study used inductive and deductive coding methods of qualitative analysis. A team consisting of the Principal Investigator and two graduate research assistants analyzed qualitative data from a group of novice and expert participants in Dedoose Version 8.0.35. Deductive coding involved the development of fifteen first-order codes. We created a list of three codes (Head, Hand and Heart) based on the Three Apprenticeships Model [31]. Previous literature on the "Heart" construct in engineering education informed our list of nine codes to represent values (e.g., empathy and compassion) [32]. In addition, existing literature assisted in the development of three codes for Expert/Novice differences and behaviors in small group interactions. Forty-five second-order codes were created using both existing literature and inductive coding methods. For example, existing literature informed the majority of the codes for behaviors in small group interactions (e.g., agreeing and joking) [27, 28]; however, an additional code, interjection, was included due to the number of times participants interrupted one another during the focus group interview. An inductive approach involves the development of codes derived from the data, rather than existing literature. Inductive coding involved analyzing the novice and expert transcripts, keeping research questions and supporting literature in mind, to find evidence for core construct codes (head, heart and hand) as well as expert and novice descriptor codes. Fifteen of the forty-five second-order codes are inductive codes derived from the data. Codes were compiled into a codebook and discussed with the Principal Investigator during weekly research team meetings.

5.4 Qualitative Research Findings

Codes were applied to responses that exemplified expert or novice qualities (e.g., deeper understanding of problems and limited experience with designing for unique needs). Professionals in the engineering industry exhibited more qualities that align with those of an expert. For example, one participant stated "it's more than just to know the [building] code, it's to understand the [building] code," indicating that the person working on the project needs to know all of the consequences of adhering to or violating a given building code, which research assistants coded as 'deeper understanding of problems.' 272 codes in total were applied to the expert focus group transcript. A total of 143 codes were applied to the novice transcript as research assistants found evidence for limited experience and solutions when designing for unique needs. This is not surprising given the few experiences students working on design projects during their undergraduate career.

Interestingly, despite the difference between participants in terms of novice/expert status, there is similar representation of the 'hand' codes for both groups (64 codes for experts and 48 codes for novices). This is interesting because during the focus group interview, the principal investigator asked participants what advice they would give to students who want to enter this field. Expert participants emphasized the importance of technical and communication skills (constructs of 'hand'). For example, one expert participant stated "You have to listen. Be a good listener." However, their responses to questions that aimed to better understand their design process reflected almost the same number of 'hand' codes as the novices' responses. This follows the "do as I say, not as I do" idiom in that experts encourage new professionals to be good listeners and utilize advanced technology like virtual reality, however, the number of times they mentioned such topics when discussing their design approach was the same as novices.

5.5 A Comparative Look at the Head, Hand and Heart

A total of 121 codes that represented 'head' constructs were applied to experts' responses, 17 were applied to novices' responses. 64 'hand' codes were given to experts' responses and 48 were given to novices' responses (see Table 3). 87 'heart' codes were applied to experts' responses and 78 were given to novices' responses (see Table 3). At a glance, there is a stark difference between the 'head' codes for novices and experts. Novices mentioned head skills much less than experts, particularly pragmatic skills. For example, when asked how they might approach their design for an audience with unique needs, one expert responded:

> "When I review designs for ADA, they have a sequence that you do it in. First of all, the parking lot. Make sure there is an accessible parking space, then a route to the front of the building, and then to the restrooms, then the drinking fountain and then to the front desk."

This suggests that experts may spend much of their time focused on the logistics of the design process rather than steps that would involve communication skills (hand) or empathic responses when faced with an ethical dilemma (heart). There appears to be an underlying tone of pragmatism (head) in the experts' responses, which is different when compared with the tone of the novices' responses. Looking at the 'Hand' codes, zero novices mentioned listening abilities, which suggests a lack of understanding of their importance. Despite this discrepancy, all other 'Hand' codes were mentioned a similar number of times in both groups. 'Heart' codes were also similar overall, but had some discrepancies in terms of which codes were prioritized. Of the 87 'heart' codes applied to the expert data, 51 of those represented the category 'user's needs,' followed by 'safety' in which 18 were applied. Examining the novice data, 33 of the 78 'heart' codes represented 'user's needs' followed by 17 codes representing 'compassion.' Both experts and novices emphasized 'user's needs' in their responses; however, each group discusses user's needs from a different perspective. There is evidence that novices think of user's needs from a compassionate perspective. Pairing the 'user's needs' code count with the second most applied code, "compassion," suggests novices may think of user's needs in terms of relating kindness to the populations in which they aim to design for. To give an excerpt example, one participant stated:

> "Maybe there is a constant problem that a majority of the community faces in their day-to-day lives. Maybe that is something we would focus on."

That response differs from one given by an expert:

> "I need to comply with ADA. I can't design a restroom that is smaller than what is required by the guidelines. So I design it for handicapped people before I think of fully healthy people."

Both responses suggest thoughtfulness of the user's needs; however, in different tones. The code 'safety' was applied second highest for the experts, suggesting that there is more concern given to the safety of the structure for a user. In addition, pairing these codes with those under 'head' indicate that experts might be thinking of user's needs from a pragmatic stance rather than one that aligns with personal values.

Table 3. Expert/Novice Head, Hand and Heart Codes

	Descriptors	
Codes	**Experts**	**Novices**
Head	**121**	**17**
Application of Knowledge	12	2
Decision Making	2	0
Pragmatic Skills	94	5
Problem Solving	13	10
Hand	**64**	**48**
Ability to Listen	14	0
Communication	19	19
Physical Skills	1	7
Technical Skills	30	22
Heart	**87**	**78**
Community Involvement	3	13
Compassion	1	17
Empathy	8	5
Ethical Reasoning	1	2
Humanitarian	0	0
Humanized	0	0
Safety	18	6
Solidarity	5	2
Trust	0	0
User's Need	51	33

6. Convergence & Discussion of Findings

Research suggests heart values such as empathy and compassion should be emphasized equally as head and hand concepts in engineering education [32] (Hess et al., 2012); however, it is unclear how these three concepts are emphasized by experts (i.e., professionals in the field) and novices (i.e., students) in the field. The present convergent mixed methods study found both similar and divergent results. The combined results suggest that the current engineering curriculum is still in need of a balance between head, hand and heart concepts. Experts and novices emphasized head and hand concepts the most in results from the focus group data; however, only novices emphasized the importance of heart values in both sets of results.

The quantitative study found that experts and novices differ in their approach to solving problems (a major component of engineering). Based on Dufrense's model of problem solving processes [33], experts have a rich knowledge base which allow them to make bidirectional connections between work-related concepts, while novices have a clustered knowledge base made up of weak connections. Therefore, novices might emphasize values that relate to the 'big picture' (i.e., how individuals might be impacted by design) rather than emphasize the details or practical considerations of the design process (e.g., safety concerns). On the other hand, experts are able to make more connections between work-related processes. For example, an expert may consider both ethical and legal aspects of the design prior to thinking about how the end result may impact the community it aims to serve. Practicality (e.g., safety concerns) might increase as individuals become experts in their field, and as a result, less importance may be placed on values like compassion (i.e., thinking of the impact that a design will have on others). At the same time, it is important to think about the implications of this. For example, if novices value compassion early on maybe that could be taken into account as a way to motivate students and keep them interested in the field rather than focus on maybe what experts think should be emphasized early on, like safety concerns. Could there be a 'time and place' for emphasizing certain values that will lead to a well-rounded engineer?

The qualitative study provides evidence that experts and novices in the design field have different approaches when designing for users with unique needs. Notably, expert engineers tended to utilize head concepts more than novice engineers, specifically pragmatic skills (e.g., budgeting, safety codes). However, both expert and novice engineers tended to have similar utilization of heart and hand concepts. Interestingly, when experts were asked to provide advice for future engineers, they emphasized hand values (e.g., listening), but do not appear to emphasize hand values in their own work. This was corroborated by the novice engineers who also stated that the most notable advice that they received was relating to hand concepts (e.g., technology). The findings of this study highlight previous research that suggests that experts have a deeper understanding of problems and integrate different sources of information faster [10]. Furthermore these findings provide evidence that expert and novices differ in their design emphasis [12].

From the results of the qualitative study, it appears that novice engineers tend to lack proper experience (e.g., class examples, projects) that allows for them to practice designing for users with unique needs. When asked about their experience in this realm of design, novice engineers replied that they mostly had examples that were strictly about structural design without users' needs as a requisite. On the other hand, expert engineers appeared to have ample experience designing for users with unique needs and would mostly rely on their pragmatic, or head values in the design process. Clearly, it is important that novice engineers are properly prepared to design for the diverse clientele that they will be employed by in the future.

Across both quantitative and qualitative studies, experts emphasized the importance of safety. From the qualitative study, experts provided context to the significance of safety. Although expert and novice engineers tended to use a similar amount of terms related to heart values, there was a different connotation between the two groups. Specifically, it appears that novices took a genuinely heart-led approach that emphasized compassion and user's needs while novices took a more pragmatic approach, pairing user's needs with safety concerns that were mostly in the context of adhering to building codes and avoiding future issues for themselves and their employer. Though the integration of heart values in engineering programs has not been emphasized, it appears when tasked with designing for users with unique needs, novice engineers continue to underscore the importance of heart values in their design. It is therefore possible that when student engineers transform into professional engineers, their personal values may start to diminish, as more pragmatic skills take priority.

The results diverge only for the novice participants. Novices reported an emphasis on empathy early on in engineering education; however, based on focus group data analysis, novices emphasized compassion. While concepts both represent 'heart' and in some ways are related (can't have empathy without compassion and vice versa), they were defined as two distinct values in the survey in Study 1. Examining this difference on a practical level, may not be so significant as empathy and compassion are similar to one another.

Prior literature consistently has argued for the equal representation of 'heart', 'head', and 'hand' concepts in engineering education; however, the current engineering curriculum appears to lag behind this research with the continued emphasis on more technical- and knowledge-based methods (Hess et al., 2012; Strobel et al., 2014). The results from Study 1 and 2 coincide with traditional engineering education methods with an emphasis on technical skills like problem solving and modeling (Adams et al., 2011; Schirra, 2001). The experts in the focus group interview described their approach to design similarly to how engineers historically view their part in the design process as a 'disengaged problem solver' [31]. Experts emphasized 'safety' in their survey responses and, in the focus group interview, discussed safety with a pragmatic underlying tone (e.g., ensure safety to avoid legal allegations). Previous research has found a more pragmatic approach to be common when working on engineering projects, where human relationships were not taken into account as much as a mathematical solution to a project [32]. Similar to the findings from the article by Strobel et al. [18], in which many of the engineering faculty participants were unfamiliar with terms associated with empathy, 'heart' focused values were not emphasized as much as 'head' and 'hand' concepts by experts in both survey reports and focus group analysis. Novices also emphasized 'hand' concepts in their approach to design, which again coincide with how engineering concepts have been taught with more importance placed on technical skills rather than 'soft skills' (e.g., showing empathy and compassion towards others) [34]. Novices reported that 'empathy' should be emphasized earlier in engineering education; however, when novices described their design process during the focus group interview, they emphasized technical skills with an underlying tone of compassion towards the users. This incongruence could be a result of being a novice in the field and having a lack of experience with issues they would not have otherwise considered (e.g., conflicting building codes).

7. Limitations

This study is not without limitations. The generalizing of findings in the quantitative portion might be limited to engineering students in higher education. Engineering students in secondary education may have different needs and therefore another perspective on which values should be emphasized in their curriculum. Limitations may also exist with respect to how Study 1 variables were measured. For example, the values 'compassion' and 'empathy' might be too related to one another for a participant to differentiate between the two and assign a ranking. In addition, a ranking method was used to explore how experts and novices differ in their perception of 'heart' values in engineering education; however, future studies should further assess their perceptions using other forms of data (e.g., surveys).

The qualitative portion had a very small sample size. In addition, it is important to note that there was a substantial difference in time between the novice (approximately 45 minutes) and expert (approximately 90 minutes) focus groups in Study 2. However, it is interesting to note that despite the interviews lasting different lengths, the quantity of hand and heart codes were comparable between expert and novice engineers.

Lastly, a limitation to this study was the lack of differentiation for safety as a heart value or a pragmatic, or head-based, value. From the results of this study, it is clear that safety can fall into different contexts, which will be intriguing to study further in the future.

8. Future Directions

Future research may further examine how engineering curriculum can integrate heart, head, and hand values as the Carnegie Foundation for the Advancement of Teaching [1] suggested. Clearly heart values are an important facet of engineering design, which both expert and novices emphasize. However, when explicitly asked what advice was the most beneficial to the training of novices, both experts and novices stated hand values. There appears to be incongruity between the literature (e.g., Carnegie Foundation for the Advancement of Teaching) and current expert/novice engineers' opinions as the most important value to emphasize in the instruction of future engineers. We encourage engineering educators to continue investigating methods to blend suggestions from engineering education literature with the expressed desires of current expert/novice engineers when designing engineering curriculum.

9. Conclusions

Using a convergent parallel mixed methods research design and Shulman's Three Apprenticeships framework, this study investigated expert and novice perspectives on the priority of affective constructs in undergraduate education and their approach to designing facilities for users with needs different from their own. While many studies focus on experts or novices independently, this study was designed to leverage both to facilitate a comparison between the two groups. Though research suggests heart values should be emphasized equally as head and hand concepts in engineering, the results of this study indicated that these are out of balance, with a heavier emphasis on the technical (head) skills. Results also suggested that experts and novices may have different perspectives on which values should be emphasized earlier versus later in civil engineering education. Broadly speaking, this study highlights the importance of examining affect-related values in civil engineering education, the results of which have implications for improving future instruction. Engineering education must guide students in understanding the importance of the head, hand, and heart dimensions, each of which is critical for holistic engineering design. It also suggests that educators should emphasize certain values (e.g., compassion) earlier in the curriculum to assist in the development of well-rounded engineers. By leveraging the perspectives of both experts and novices, this study has contributed to a diverse understanding of how civil engineers prioritize affective constructs, and points to future improvements in instruction that will prepare civil engineering students for the challenges they will face in their careers.

References

1. W. M. Sullivan and M. S. Rosin, Carnegie Foundation for the Advancement of Teaching, *A new agenda High. Educ. Shap. a life mind Pract.*, 2008.
2. A. Johri and B. M. Olds, *Cambridge handbook of engineering education research*, Cambridge University Press, 2014.
3. D. R. Simmons, E. G. Creamer, and R. Yu, Involvement in out-of-class activities: A mixed research synthesis examining outcomes with a focus on engineering students, *J. STEM Educ.*, **18**(2), pp. 10–17, 2017.
4. D. R. Simmons, G. Young, S. G. Adams and J. P. Martin, Non-Curricular Activities Help African-American Students and Alumni Develop Engineer of 2020 Traits: A Quantitative Look, in *Proceedings of the Annual ASEE Conference*, 2014.
5. J. S. Russell and W. B. Stouffer, Survey of the national civil engineering curriculum, *J. Prof. Issues Eng. Educ. Pract.*, **131**(2), pp. 118–128, 2005.
6. J. R. Herkert, Engineering ethics education in the USA: Content, pedagogy and curriculum, *Eur. J. Eng. Educ.*, **25**(4), pp. 303–313, 2000.
7. N. S. Grigg, M. E. Criswell, T. J. Siller, D. G. Fontane, D. K. Sunada and L. Saito, Integrated civil engineering curriculum: Five-year review, *J. Prof. Issues Eng. Educ. Pract.*, **130**(3), pp. 160–165, 2004.
8. B. Abernethy and D. G. Russell, Expert-novice differences in an applied selective attention task, *J. Sport Exerc. Psychol.*, **9**(4), pp. 326–345, 1987.
9. K. Carter, K. Cushing, D. Sabers, P. Stein and D. Berliner, Expert-novice differences in perceiving and processing visual classroom information, *J. Teach. Educ.*, **39**(3), pp. 25–31, 1988.
10. M. T. H. Chi, R. Glaser and M. J. Farr, The nature of expertise. Hillsdale, NJ: L. Erlbaum Associates, 1988.
11. A. Ruckpaul, T. Nelius and S. Matthiesen, Differences in analysis and interpretation of technical systems by expert and novice engineering designers, *Proc. Int. Conf. Eng. Des. ICED*, **2**(DS 80–02), pp. 339–348, 2015.
12. C. J. Atman, R. S. Adams, M. E. Cardella, J. Turns, S. Mosborg and J. Saleem, Engineering Design Processes: A Comparison of Students and Expert Practitioners, *J. Eng. Educ.*, 2007.
13. S. R. Daly, R. S. Adams and G. M. Bodner, What does it mean to design? A qualitative investigation of design professionals' experiences, *J. Eng. Educ.*, **101**(2), pp. 187–219, 2012.
14. D. Kilgore, C. J. Atman, K. Yasuhara, T. J. Barker and A. Morozov, Considering context: A study of first-year engineering students, *J. Eng. Educ.*, **96**(4), pp. 321–334, 2007.
15. L. S. Shulman, The Wisdom of Practice: Essays on Teaching, *Learn. Learn. to Teach, SM Wilson San Fr. Jossey-Bass*, 2004.
16. L. Shulman, The signature pedagogies of the professions of law, medicine, engineering, and the clergy: Potential lessons for the education of teachers, in *Talk Delivered at the Math Science Partnerships (MSP) Workshop: "Teacher Education for Effective Teaching and Learning"* Hosted by the National Research Council's Center for Education February, 2005, pp. 6–8.
17. Y. Sipos, B. Battisti and K. Grimm, "International Journal of Sustainability in Higher Education," *Int. J. Sustain. High. Educ. Int. J. Sustain. High. Educ. Iss Int. J. Sustain. High. Educ.*, **9**(4), pp. 68–86, 2008.
18. J. Strobel, J. Hess, R. Pan and C. A. Wachter Morris, Empathy and care within engineering: Qualitative perspectives from engineering faculty and practicing engineers, *Eng. Stud.*, **5**(2), pp. 137–159, 2013.
19. J. Walther, S. E. Miller and N. W. Sochacka, A model of empathy in engineering as a core skill, practice orientation, and professional way of being, *J. Eng. Educ.*, **106**(1), pp. 123–148, 2017.
20. N. D. Fila and J. L. Hess, *In their shoes: Student perspectives on the connection between empathy and engineering*, 2016.
21. J. E. Mills and D. F. Treagust, Engineering education – Is problem-based or project-based learning the answer, *Australas. J. Eng. Educ.*, no. June, 2003.
22. M. Itani and I. Srour, Engineering students' perceptions of soft skills, industry expectations, and career aspirations, *J. Prof. Issues Eng. Educ. Pract.*, **142**(1), p. 04015005, 2016.
23. E. J. Coyle, L. H. Jamieson and W. C. Oakes, EPICS: Engineering projects in community service, *Int. J. Eng. Educ.*, **21**(1), pp. 139–150, 2005.
24. D. E. Goldberg and M. Somerville, A whole new engineer, *Coming Revolut. Eng. Educ. Douglas MI Threejoy*, 2014.
25. A. Field, J. Miles and Z. Field, Discovering statistics using R, London: Sage Publications, 2012.
26. R. A. Krueger and M. A. Casey, Focus Groups: a Practical Guide for Applied Research, Sage, *Thousand Oaks, CA*, 2000.
27. A. J. Onwuegbuzie, W. B. Dickinson, N. L. Leech and A. G. Zoran, A qualitative framework for collecting and analyzing data in focus group research, *Int. J. Qual. methods*, **8**(3), pp. 1–21, 2009.
28. E. Rothwell, Analyzing focus group data: content and interaction, *J. Spec. Pediatr. Nurs.*, **15**(2), pp. 176–180, 2010.
29. V. Popovic, Expert and novice user differences and implications for product design and useability, in *Proceedings of the Human Factors and Ergonomics Society Annual Meeting*, 2000, **44**(38), pp. 933–936.
30. J. L. Hess, J. Strobel, R. Pan and C. A. W. Morris, Practicing engineers' perceptions of empathy and care: Derived exploratory factor structure from a 37-item survey, in *2014 ASEE Annual Conference & Exposition*, pp. 24–991, 2014.
31. S. D. Sheppard, K. Macatangay, A. Colby and W. M. Sullivan, Preparing the Next Century Engineer, in *Educating Engineers: Designing for the Future of the Field*, San Francisco: Jossey-Bass, 2008.
32. J. L. Hess, J. E. Sprowl, R. Pan, M. Dyehouse, C. A. W. Morris and J. Strobel, Empathy and caring as conceptualized inside and outside of engineering: Extensive literature review and faculty focus group analyses, in *American Society for Engineering Education*, 2012.

33. R. J. Dufresne, W. J. Gerace, P. T. Hardiman and J. P. Mestre, Constraining novices to perform expertlike problem analyses: Effects on schema acquisition, *J. Learn. Sci.*, **2**(3), pp. 307–331, 1992.
34. J. Schirra, Computer Game Design: how to motivate engineering students to integrate technology with reflection, *4Th Uicee Annu. Conf. Eng. Educ. Conf. Proc. Innov. Eng. Educ.*, no. February, pp. 165–169, 2001.

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