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Practicing Engineers' Definition of Their Expertise: Emergent Themes and Frequency by Gender Identity and Role Change into Management

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Introduction & Background

This full paper seeks to characterize how gender identity and role change into management affect practicing engineers' descriptions of their expertise. Expertise is defined through three main attributes: (1) expert knowledge – depth of knowledge (2) expert reasoning – deductive process that is inferentially based on an expert's knowledgebase, (3) and expert memory – working memory rather than short-term memory [1]. Development of expertise comes by gaining knowledge and understanding the details of a problem that are most important, which leads to changes in working memory (e.g., information stored is larger, information stored is less likely to be disrupted by less relevant details, information recall is flexible, and information stored becomes part of long-term memory and can be retrieved even when it is needed unexpectedly) [1].

We seek to characterize salient differences in expertise between groups to better understand the emergent patterns in participants' perceptions of their personal expertise. Our analysis examines pattern frequency by gender identity and role change into management. We focus on gender identity because women continue to be underrepresented in engineering [2]. This underrepresentation suggests a need to explore and understand the perceptions of those who do enter the field. Social role theory suggests that female expertise is frequently unacknowledged in male-dominated settings, regardless of educational history or technical experience [3]. Female expertise is much less influential in male-dominated environments because the majority automatically devalue female expertise at a surface level [3]. Applying this theory to our work suggests that female engineers may have an increasingly difficult time having their expertise recognized by their male co-workers. The lack of recognition of female expert knowledge from their work environment could influence women's subsequent comfort in identity as an expert and descriptions of their expertise.

The focus on role change into management, specifically from technical to managerial, stems from the commonality of this type of transition for practicing engineers [4]. The context of management is quite different from a technical role; managerial work requires extensive contextual knowledge [5] that does not typically align with general understanding of engineering skills. Lower-level managers report relying on contextual knowledge and job-specific experiences to a greater extent than experienced managers [5]. This contextual knowledge in engineering could refer to technical backgrounds. This difference in context suggests that engineers who transition into managerial roles may rely less on their technical background as they progress further into their careers, which can affect an individual's perception of their expertise. A study of project managers showed that having technical skills are the bare minimum for the job [6]. Having exceptional professional skills is what leads to success in roles with greater responsibilities in management [6]. This emphasis on professional skills could allude to a shift in expertise from technical to professional skills when switching to a managerial role in later career stages. The transition away from technical expertise may be difficult for engineers to navigate, as professional skills align less with the technical skills associated with early career.

We present our examination of practicing engineers' definition of their expertise by gender identity and role change into management using data collected from a larger effort to disentangle the construct of intuition from expertise in engineering [7]. The following sections describe our methods used for data collection and analysis, emergent themes, conclusions, and future work.

Methods

We interviewed 17 practicing engineers and analyzed these interviews for emergent themes through thematic coding [8-10]. We employed a robust process of codebook development with multiple coders engaging in the process to ensure code-agreement.

Sample

A sample of 17 practicing engineers from various engineering disciplines was interviewed for this study. As experience has been previously identified as a core contributor to expertise development [11], a criterion for inclusion was a minimum of 5 years of work experience.

Nine participants identified as women and eight as men. Six of the seventeen participants have had a role change into management during their careers, four of whom identified as women. Table 1 summarizes relevant participant demographics.

Table 1. Sample Population

Demographics	Number of Participants
Men	9
Women	8
Role change into Management	6
No Role change into Management	11
6 – 10 Years of Experience	7
11 – 15 Years of Experience	1
16 – 20 Years of Experience	1
21 – 25 Years of Experience	2
26 + Years of Experience	6

Data Collection

Data was collected in Spring 2020 through semi-structured interviews lasting on average 45 minutes. Interviews were conducted using the online conferencing tool Zoom and were recorded for subsequent transcription. Three members of the research team attended each interview; one researcher led the interview, while the remaining two observed and sent private messages to the lead to provide input and direction as needed. This approach was used to ensure protocol implementation consistency.

The interview protocol was designed to capture the interviewee's: (1) academic and professional background, (2) development of expertise, (3) decision-making and problem-solving approaches used in the workplace, and (4) definition and perception of engineering intuition. This study

focuses solely on responses related to participants' definition of their expertise posed at the beginning of the interview. Information on the development of the interview protocol and preliminary codebook has previously been published [7], [12].

Data Analysis

A codebook of emergent themes was developed in alignment with best practices in qualitative coding [8-10]. First, three team members participated in identifying and discussing emergent themes for each of the seventeen interviews. Each researcher coded emerging ideas individually before coming together to discuss and categorize emerging themes collectively. A fourth team member was occasionally brought in to code an interview to ensure that the codes were comprehensible and consistent from an outside perspective. This process resulted in a final codebook containing agreed-upon emergent themes from across all 17 interviews.

All interviews were then re-coded with the final codebook. This process produced a singular coded transcript for each interview, which contained the discussed and agreed upon codes. Each coded interview was captured digitally using the qualitative coding software Dedoose, where we transferred the agreed upon codes into a singular version. A primary researcher transferred the final coded version into Dedoose, followed by a secondary researcher who checked for consistency. Demographic information was also added as descriptors for each respective interview.

Data Analysis was subsequently completed in Dedoose. Responses to the question *"How do you define your expertise?"* were analyzed for this study. The frequency of various codes was tabulated across demographic information. Initial results revealed a difference in the frequency of the parent code *mindset* within the descriptors of *gender* and *role change into management into management*. Each emergent code was analyzed versus each descriptor separately to identify intersections with gender identity and role change into management. All results are reported as normalized percentages and account for differences in size of population subgroups.

Results and Discussion

Two distinct patterns emerged when analyzing participant's definitions of their expertise by gender and role change into management: (1) variation in the type of skill or knowledge reported, and (2) active identification with personal expertise. These patterns are captured in four sub-codes – technical skill, professional skill, passive ownership of expertise, and active ownership of expertise (Table 2). Table 3 shows the normalized frequency of each code by gender and role change.

Technical versus Professional Skills

Men reported having technical skill expertise (56%) and/or professional skill expertise (66%), at a greater frequency than women participants. Men also reported more than one skill as their expertise (38% of men) more frequently than women did (11% of women), which potentially explains why men have a greater frequency of both technical and professional skill code occurrences. Participants who have had a role change into management in their career were far more likely to report professional skills as expertise; 76% of professional skill codes were

reported from participants with role change into managements. Comparatively, 60% of technical skill expertise was reported from participants who have not undergone a role change into management.

Table 2. Definitions of Codes

Parent Code	Sub-Code	Definition	Examples from Interviews
Type of skill or knowledge reported	Technical Skill	Qualities acquired by using and gaining expertise in performing physical or digital tasks [13].	"My expertise is high speed boundary layer transition…"
	Professional Skill	Personality traits and behaviors; the behaviors you display in different situations [13].	"Being able to, to sit and look at things objectively."
Identification with personal expertise	Passive Ownership of Expertise	Lack of confidence in identifying with personal expertise.	"I wouldn't say I have like a deep expertise in something."
	Active Ownership of Expertise	Presence of confidence in identifying with personal expertise.	"I know the products of my company better than probably somebody else who just quickly looked at the data sheet."

Table 3. Subcode Frequencies by Gender or Role Change into Management

	Gender		Role Change into Management	
	Men	Women	No Role Change into Management	Role Change into Management
Technical Skill	56.3%	43.8%	60%	40%
Professional Skill	66.3%	33.7%	23.8%	76.2%
Active Ownership of Expertise	55.9%	44.1%	50%	50%
Passive Ownership of Expertise	69.2%	30.6%	30.4%	69.6%

Active Ownership versus Passive Ownership of Expertise

Participating men in our study more frequently reported both active and passive ownership of their expertise. Approximately 69% of passive ownership codes and 56% of active ownership codes came from men. This result may be tied to men simply reporting multiple skills as their expertise more often than women. For example, one man reported both "constantly learning" and

thoroughly understanding the products of his company as his expertise. Constantly learning was marked as a professional skill, while understanding the functions of particular products was marked as a technical skill.

Passive ownership of expertise was more frequent when a participant had experienced a role change into management. About two-thirds (~69%) of passive ownership of expertise codes came from participants with a role change into management. Literature suggests that drastic shifts from technical roles managing something tangible based on years of education to managerial roles managing people causes a disparity in career identity [14]. Our data suggests a similar pattern, where engineers do not identify as readily with professional skills as they do with technical skills. This lack of identification with professional skills may be tied to the heavy association of technical skills with a specific career. The lack of identity tied to professional skills in engineering may explain the overwhelming frequency of passive ownership of expertise codes when a role change into management is present.

Intersections between Gender and Role Change into Management

Table 4 below shows the normalized frequency of each subcode with respect to the intersection between gender and role change into management. Four of the six participants (66.7%) who reported transitioning from a technical role to a managerial role were also women, resulting in some noteworthy trends at the intersection of gender and role change into management. All professional skill codes (100%) for expertise among women came from those who experienced a role change into management. Among men, professional skills codes emerged dominantly, but not exclusively, from men with a role change into management (69.2%). Professional skills were also typically reported passively. Women with a role change into management were less likely to describe technical skills as expertise (33.3% of technical skill code occurrences among women), whereas men reported technical skills at equal frequency regardless of whether they had a role change. Our results combined with the literature allude to female engineers potentially having their technical expertise further discounted as they advance towards managerial roles [3]. The prioritization of professional skills in managerial positions aligns less with the general perception of engineering being a strictly technical career. This perception may explain why women in engineering who have undertaken a role change into management passively own their expertise (i.e., they are being invalidated from their predominately male co-workers and from the accepted perception of the technical skills engineers should traditionally be skilled in). It is also interesting to note that women in our sample with 26+ years of experience transitioned to managerial roles (n=2), compared to 1 of 4 men at a similar career stage. These women were often the first, and the only, woman in their early-career technical roles as well as these managerial positions. The overall work-climate, culture, and other factors may have also influenced this trend.

Table 4. Sub-code Frequency within Gender by Role Change into Management

	Men (n=8)			Women (n=9)		
	No Role Change (n=6)	Role Change (n=2)	Total Occurrences Among Men	No Role Change (n=5)	Role Change (n=4)	Total Occurrences Among Women
Technical Skill	50%	50%	8	66.7%	33.3%	7
Professional Skill	30.8%	69.2%	7	0%	100%	4
Active Ownership of Expertise	40%	60%	9	57.1%	42.9%	8
Passive Ownership of Expertise	25%	75%	6	28.6%	71.4%	3

Conclusions and Future Work

This study provides insight into patterns across gender and role change into management with respect to definitions of personal expertise. We see that expertise is personal and unique to the individual, making it likely for there to be an attachment of identity with the statement. Our results support the influence of identity in personal perception of expertise. Gender differences show various patterns of identifications with expertise. The men in our sample more frequently reported multiple skills as their expertise, while women tended to focus on one skill. Participants who reported having a transition from technical work to managerial work also reported a greater frequency of professional skills as expertise, yet passively identified with it. These results may suggest that engineers identify less with professional skills, as technical skills are more greatly associated with engineering careers.

We hope to draw upon the findings from this study as a lens for interpreting participants' definitions of their expertise through their gender and career-role identity. Our results suggest that we need to be aware of these factors as confounding variables in a participant's definition of expertise that may have further effects on their subsequent descriptions of expertise development and perception of engineering intuition.

This work also brings to light new questions at the intersection of gender and expertise in the context of a transition from a technical to managerial role. It is striking that in our sample, both participating women with 26+ years of experience (n=2), had transitioned to managerial roles, but only one of four men with the same amount of experience made the same transition. A larger sample of practicing engineers with 26+ years of experience may shed further light on this observation.

Our conclusions indicate that identity and expertise have overlapping areas of interest. Future work will explore using existing measures of identity to provide additional insight into relationships between identity and expertise. We intend to expand our current data analysis to understand the influence of cultural background on shaping identity. We hope to strengthen our

future work with further analysis into the relationships identity holds with perceptions of expertise in conducting more interviews and continuing to review existing literature.

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