AC 2008-827: A QUALITATIVE STUDY OF THE EARLY WORK EXPERIENCES OF RECENT GRADUATES IN ENGINEERING.

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A Qualitative Study of the Early Work Experiences of Recent Graduates in Engineering.

Abstract

After several years of demanding study, new engineers graduate from higher education as professionals eager to apply their expertise to solving "real world" problems. Yet, the transition from school to the workplace involves a socialization process through which new graduates attempt to learn the specific tasks and expectations of their job and begin to integrate into the social context of the organization. Research indicates that this socialization process is important for framing new employees' experiences and forming their perceptions of work and the organization. These socialization experiences have immediate effects on job satisfaction and learning, and potentially long-term effects on turnover and commitment to the organization and profession[1, 2, 3].

This paper reports the findings of a study investigating the socialization experiences of newly hired engineers in a large U.S.-based, global manufacturing company. In this organization, new engineers encountered engineering processes of a different nature than they learned in school. The social and organizational contexts within which they worked influenced the problems and processes they experienced—often introducing greater complexity, ambiguity, and subjectivity than expected. How the new engineers in this study perceived and learned about engineering work in this organization depended to a large extent on their interactions with coworkers in their work groups. These findings provide greater description and clarification of these socialization experiences, along with the relationship of these experiences to their education.

1. Introduction

Many in industry and academia judge the preparation of new engineers for work to be less than adequate. Efforts to improve the curricula and practices of engineering education include more collaborative and socially based pedagogies (e.g., design thinking, problem-based learning, and cooperative learning), as well as more experiences based in the workplace, e.g., ABET's professional skills and the attributes of the Engineer of 2020[4, 5, 6].These efforts have recommended significant revisions to engineering curricula by expanding the content of engineering from its traditional focus on the application of math and science to broader, socially and design-based curricula. These discussions tend to focus on generalized conceptions of practicing engineers and how best to prepare students in engineering programs to acquire these competencies.

This paper focuses on an important process in the preparation of new engineers for work in organizations—specifically the socialization process through which new engineers make the transition from school to the workplace. Although socialization into practice primarily occurs in the workplace, the link between school and the workplace is arguably strongest during this transition. It is during this process that graduates in engineering learn the more about the practice of engineering in the workplace and form their perceptions of the profession and the job. Identifying the characteristics of this unique experience and its relationship to engineering education is the focus of this paper.

While most recognize it is not feasible for academia to prepare engineering students to perform specific tasks of working in individual organizations[7], there has been an ongoing debate about the relevance of the traditional curricula taught in engineering education for engineering practice[8, 9, 10, 11]. Furthermore, there has been an ongoing debate about relevant competencies and attributes required of future engineers[12, 13, 14, 15, 16]. As Barley[14] pointed out, much of this discussion focused on an epistemological or theoretical interest in engineering, not on the specifics of the work. This study focused on the specific work experiences of new engineers as they transitioned into the workplace.

In a recent study of the effectiveness of the EC2000 criteria, Lattuca, Terenzini, and Volkwein[4] found that most employers reported new graduates of engineering programs were adequately or well prepared in the areas of their abilities to use engineering, math, science, and technical skills (92%); along with abilities to learn, adapt, and grow (86%); and problem solve (82%). However, 25 per cent of employers rated the preparation of new graduates as inadequate at communication and teamwork skills and 48 per cent rated the preparation of new graduates in engineering as inadequate at understanding organizational contexts and constraints.

To understand better the context of the inadequacies described by employers, we conducted in-depth qualitative interviews with newly hired new graduates of engineering programs. Specifically, we examined the work experiences of newly hired engineers having less than two years employment at a large, U.S.-based manufacturing company. This is the period during which new employees encounter and learn the specific expectations and requirements of the job and are arguably the most aware of any differences between their engineering education and engineering practice. This is also the time when new engineers become socialized into the practice of engineering in organizational settings. Research indicates that this is a critical period for new employees in general as it forms enduring perceptions of their work, profession, and of the employing organization. There is evidence that these perceptions strongly influence new employees' job performance, job satisfaction, intentions to quit, and commitment to the organization[1, 2, 3].

This paper presents the findings of this study, followed by a discussion that considers implications for engineering education. We framed this analysis around the socialization process and the theories of social cognition and social exchange. Learning a new job is a process of learning the tasks and procedures of the job, as well as the dynamics of the social system in the organization.

2. Background: Theoretical Framework

Two theoretical perspectives informed this investigation of the socialization of newly hired engineers: social cognitive theory and social exchange theory. While many researchers of the learning process experienced by new employees (socialization) based their work on social cognitive theory[17], few researchers employed the perspective of social exchange theory. A brief review of each theoretical perspective follows.

Social Cognitive Theory

Various models of socialization describe stages through which newcomers pass as they become organizational members[3]. Learning is the common thread throughout these models as newcomers learn specific job tasks, learn the procedures of the work group, learn the expectations of management, and learn the values and mission of the organization[1, 18]. Van Maanen and Schein[2] described the socialization process by three domains of (a) learning what to do, (b) learning how to do it, and (c) learning why it is done this way.

From the perspective of the learner in a social context, social cognitive theory views learning as a complex process, which is affectively and socially constituted[19]. This is consistent with recent theories of learning, which incorporate cognitive, emotional, and social factors into a more integrated system of interdependent factors[19, 20]. For example, Yang[20] proposed a theory of knowledge comprising interactions between technical knowledge (what to do), practical knowledge (how to do it), and affectual knowledge (values, or why it is done this way). In a related manner, Illeris[19] proposed a tripartite model of learning comprising interdependent cognitive, affective, and social dimensions. There is also a correspondence between these broader views of learning and the requirements of learning in the socialization process. Encountering a novel situation (e.g., a new job) prompts newcomers to search for information to make sense of the situation[21].

Socialization is a complex process comprising multiple actors and interactions[17, 23, 24, 25, 26]. Wanous[3] found that increasing the level of interactions between the newcomer and his or her environment increased the success of socialization. However, it seems reasonable that the quality of the interaction is important—not just the level of activity. Increasing the wrong kind of interactivity may promote the wrong kind of learning. Social exchange theory addresses the quality of interactions among individuals.

Social Exchange Theory

Social exchange theory (SET) describes a type of ongoing relationship between people (actors) as a series of interactions in which actors exchange resources guided by rules of exchange, e.g., professional practices or social norms[27]. Blau[28] stated that social exchange involved the more ambiguous and relationally oriented exchange based on reciprocity or mutual exchange. Cohen and Bradford[29] posited that the basis of many organizational interactions was reciprocity.

Recent theorizing has begun to move social exchange theory beyond its behavioral and economic roots to include cognitive and affective constructs. Recently, Lawler[30] proposed an affective theory of social exchange that directly linked emotions and sentiments to actors' perceptions of fairness, satisfaction, solidarity, trust, leniency, and commitment to their exchange relationships.

Social exchange is the basis of role-making theory and leader-member exchange theory highlighting the importance of interactions between individuals in organizations. The premise of role-making theory is that organizational roles are ill-defined, and individuals negotiate and clarify roles through interactions (exchanges) between leaders and members[31]. Through these processes, the newcomer acquires information about the behavioral constraints and demands of the job, negotiates alternatives, accepts a pattern of behavior, and gradually modifies this pattern of behavior[32].

Leader-member exchange theory states that work roles are developed and established over time through a process of ongoing exchanges between a leader and member. The leader offers increased responsibility and membership benefits to the new member, and in return, the subordinate offers increased commitment and contribution to the work group. Leader-member relationships are unique to each individual dyad and may develop into high-quality relationships based on trust and respect or degenerate into low-quality relationships merely fulfilling the employment contract[33]. According to Graen and Uhl-Bien's[34] model of leader-member exchange, higher quality relationships are characterized by higher levels of trust, respect, and obligations in which the leader shares more power, information, and access with the subordinate member.

Once the newcomer is aboard, high- or low-quality relationships form quickly and tend to endure[32]. Thus, the initial interactions between the newcomer and the work group are extremely important, because they affect attitudes, satisfaction, and performance. Another important research finding on leader-member exchange theory is that perceptions of a relationship often differ significantly between the leader and the member. Studies have shown a low correlation between subordinates' and leaders' perceptions of their relationship[35]. This difference in perceptions may confound attempts to socialize newcomers by fostering misperceptions, misunderstandings, and misinterpretations of events, exchanges, and expectations during the socialization process.

These socially driven views of learning and exchange (interaction) in organizations contend that information and knowledge are not completely objective. Rather the learning, interpretation, and understanding of information is a highly interdependent social activity depending on the characteristics of the actors. From this perspective, transferring knowledge from the world of education to the world of the workplace requires an understanding of the social dynamics of engineering work. This study attempted to capture the context, as well as the process of engineering work at the stage when new engineers enter the workplace from school.

3. Research Design and Study Implementation

This study addresses the question of *how* newly hired engineers learned to practice engineering as they began new jobs in an organization. Preliminary investigations into the phenomenon of socialization through the literature and from initial interviews with practicing engineers and managers indicated that the socialization process was problematic—especially regarding the social dynamics of the workplace. The research questions guiding this study are:

- How do newly hired engineers practice engineering in the workplace?
- How do newly hired engineers learn the specific job requirements of the workplace?
- What are the factors affecting how newly hired engineers begin practicing engineering in the organizational setting?

3.1 Methodology

A qualitative case-study research approach seemed most appropriate to answer the research questions of this study. Several authors described a qualitative methodology as, not only appropriate, but also more likely to provide insights into complex social phenomena[36, 37, 38]. Stake[39] described qualitative case-study research as an appropriate design for acquiring an in-depth understanding of the complex interactions and functions of people in the context of a specific situation. Also, Yin[35] described case-study designs as relevant strategies for research questions of *how* and *why*, as well as relevant strategies for research focused on contemporary events within a real-life context and in which the researcher had little to no control over events. Thus, the characteristics of this study (examining a complex social phenomenon in context) seemed most appropriate to a qualitative case-study research design.

3.2 Sampling and Data Collection

The organization in this study was a global manufacturer based in the U.S. The mission of engineering in the organization was to produce advanced, high-quality products quickly and efficiently—products that customers wanted. Consequently, the organization assigned many of the newly hired engineers to work groups that were developing, validating, and bringing to production new technologies to meet the highly competitive demands of the market. Most of the newly hired engineers were mechanical and electrical engineers.

Following the logic of theoretical or purposeful sampling[37, 41], managers in the organization identified individuals to interview for the purpose of collecting rich, in-depth information addressing the research questions. All participants had less than two years experience with this organization; and included male and female participants, as well as different ethnic groups. Also, participants came from various work groups in the organization. Work groups were organized around specific processes or systems, such as software, electrical, or mechanical systems, aerodynamics, validation, testing, and design. The size of the work groups ranged from approximately eight to 20 individuals who reported to a manager. Interviews included 17 new graduates (newly hired engineers, recent graduates starting their first job out of school).
The 17 participants in this study were interviewed in January and February of 2007. Interviews lasted from 50-90 minutes and were recorded by the researcher. A professional transcriber converted the recordings to text and the researcher checked the transcriptions for accuracy with the original recordings.

The interviews were semistructured, following the Critical Incidents Technique[42, 43, 44]. The questions used in the interviews asked participants to recall a project or problem assigned to them in which they had to use their technical expertise to resolve. Each participant was asked for two projects or problems and to describe for each how they became aware of this assignment, who assigned it to them, what kind of background information they received, how they defined the problem, and how they resolved the problem. Participants were also asked how their education in school related to this assignment and to their work in general. Finally, participants were asked how their education could have been improved to give them a better preparation for the workplace.

The analysis of the text (data) followed qualitative analysis procedures recommended by Miles and Huberman[45] and Strauss and Corbin[41]. Four steps constituted the analysis process: (a) review the transcripts and attach predetermined codes to statements that described engineering experiences related to problem solving; (b) retrieve all statements coded as problem-solving experiences, and proceed to open-code[41] these statements at a finer level of detail, staying close to the participants' language; (c) sort the resulting open codes into patterns and categories; and (d) identify the thematic patterns and categories emerging from these data.

4. Findings

Analysis of the texts from the interviews identified a number of tasks and experiences related to problem solving. These tasks generally fell into four major categories labeled:

- The problem solving process
- Working within the work group (social system).
- Working within the organizational system.
- Managing individual effort.

Participants described their work as a process comprised of tasks from each of these categories. We describe each of these categories in greater detail in the following sections, keeping in mind that new engineers described these categories as relatively interdependent aspects of their work.

The Problem Solving Process

This category of new engineers' work typically involved what many participants believed to be the "real work" of engineering. Most participants defined engineers as problem solvers and engineering as a method for solving problems. They described this method based on "a way of thinking" they learned as a result of their educational experience. Analyzing the content of the interviews specifically relating to problem-solving work found four subthemes describing this process in more detail. The problem-solving process or way of thinking began with individuals trying to: organize, define, and understand a problem; gather, analyze, and interpret data; document and present the results; and project-manage the overall problem-solving process

Organize, define, and understand a problem. As newcomers to the organization, new engineers typically received first assignments in which others had defined the problem and their task was to finish the process or provide assistance to a coworker assigned to the problem. For example, "I was working with him to figure out what it was coming from because they were... They heard the noise but nobody knew what it was from. So we had to kind of figure out what it was."

Often there is the need to interact and understand another's perspective on the problem: "Well, he said he had some ideas of how to test it and then we ended up getting together again later and working through how to set it up and stuff,", though sometimes the work is fairly solitary: " This was me, go out in the vehicle, collect a bunch of data, find the problem in these data, look at the software, see how the software says it should have worked, and then fix the software. . ."

Several newcomers described the difficulties of defining the problems they tackled. Compared to the problem solving work they did in school, workplace problems often lacked data and were more complex and ambiguous with far more variables. One participant described this ambiguity as follows: “And so they were kind of like—well, I don’t really know what to tell you is the right answer, so you guys all have to go figure it out.”

An important task in problem solving was deciding what the scope of the problem was, which variables were important to consider, and which variables were not important to consider. In some cases, a frequent complaint was not knowing the “big picture” in which the problem was grounded. For example:

> I mean in school it’s very textbook. They always try and model everything in a mathematical sense in school. And in the real world, it’s a lot more difficult to model things. It’s just there’s a lot more variables involved and there’s the unsurety too of whether or not you’re modeling it right. Are you following the right procedures and principles? And stuff like that.

Gather, analyze, and interpret data. All the newcomers gathered and analyzed data in a similar manner to what they learned at school. Several new engineers explained how they learned to recognize whether the data they gathered and analyzed were reasonable given the parameters of the problem or model.

> just learning how to interpret results and how to look at things and—was that a reasonable answer? It may not be exactly right, but is it at least in the right ballpark? That kind of analyzing of results, I would say I learned in school and was helpful with this project. I think you just gradually learn it over the years at school. [*From*] homework and exams and doing tests in the lab and stuff like that.

Some newcomers discussed their exposure to the different interests in the organization that affected the results and decision processes related to their work. A few discussed how they were learning to interpret data and to anticipate how others interpreted data. This interpretability of data was a new experience to many. For them, the nature of the data they used in school was relatively objective and important to solving the problem. In contrast, in the workplace, they found that data did not always carry this objective or priority status. One participant described learning how different people perceive data differently: “[*I* am] definitely learning more about how to present my data to people, . . . It’s a huge difference in how people perceive your data depending on how much they know.”

Document and communicate the results. Newcomers also reported their awareness of the importance of documentation and communication to their work. This included communicating with others before, during, and after a project, as well as communicating the results to interested groups. In some cases, little documentation existed—especially regarding the background and context of the project. One participant reported:

> the person in charge of this system, he already had a test procedure that he had started writing, but he had written that and it wasn’t really complete, like two, three years ago. So it’s kind of like he handed that over to me and I had to update it and make changes and kind of get it up to date with the new spec that was in the system now.

Others were assisted by more experienced coworkers taking pains to develop thorough documentation, as described by this participant:

> Luckily, my DE [*design engineer*] was very on top of things and he stayed very late that night and made a 60-page PowerPoint explaining every single cut, mix, screw, bolt, every single thing you do. And we went down there the next morning and walked them [*technicians*] through the whole thing and finally they agreed to change the paperwork and [*asked us*] to just fill out what you're sending and why and just a half a sentence about what you want us to do, and attach that PowerPoint and we'll get it done.

Manage the problem-solving process. In addition to working through the problem-solving process, newcomers also managed the process in many cases. This required the use of project management skills to coordinate efforts among themselves, various people and groups, manage multiple stages in the process, maintain standards, and meet key deadlines.

Summary of the Problem-Solving Process.

Nearly all the new engineers reported or implied that they perceived the problem-solving process to be real engineering work—especially when it focused on gathering and manipulating data. However, they also described a large amount of social interaction and social influence on the problem-solving process, which many implied was a major difference between how they learned problem-solving in school and how they practiced problem-solving in the workplace. For example, one participant stated that; "Well, a lot of the problem solving here seems to be the people side. Getting who you need when you need and knowing who knows what . . ."

Working within the Work Group (Social System)

In addition to resolving technical problems, new engineers reported having to learn the constraints of the social system within their work groups. The social system (coworkers and manager) held certain expectations and presumptions for how to solve problems and what should be the outcomes. New engineers relied on their coworkers and managers to learn the "subjective" aspects of their work. It seemed that, in many cases, the social system mediated the problem-solving process.

New engineers reported that throughout the problem solving process they interacted with others to learn, collaborate, relate, and influence. General themes describing how new engineers worked with the work group included: developing relationships with others, learning from others, collaborating with others, and influencing others. Most new engineers understood that their coworkers were an important source of information on the job. Yet some implied they did not anticipate the need to develop good relationships with coworkers as a prerequisite to doing their work. One participant's manager explained the importance of relationships this way:

> It's like around here you're going to run into a lot of people that are very laid back, and if they don't think you're priority or your work's priority, you'll be on the back burner for a year on something. And so you'll learn that you've really got to network and really learn

people around here and really, really get to know them on a personal level and earn their respect.

Learning from coworkers was the primary method of learning on the job. Along with this, many new engineers described their reliance on coworkers to not only provide information about their work, but also provide the context and interpretation. Several reported high levels of ambiguity in their work requiring help from others with more experience. One participated reported; “I was asking my coworkers a lot of those type of questions. Like -- why are we doing this? What exactly is this doing? You know, just like getting more explanation on why we’re doing that stuff.”

Interactions with coworkers also included coordinating work among different individuals within the work group, as well as outside of the work group. In some cases, the tasks of the job required new engineers to present and influence others to adopt certain findings or proceed in a certain direction on the project.

> you have to be very quick . . . and defend the changes you want to make. I mean if you’re adding cost to the [*product*], you’re making a lot of people mad or something’s been designed and you’re going back to the engineers over there and saying -- I’m sorry, this isn’t going to cut it. You’re ruffling a lot of feathers.

Summary of Working within the Work Group (Social System).

This category of experiences describes the context of the social system within which new engineers learned what to do, how to do it, and why it was done that way. A high level of ambiguity or a lack of documentation regarding the work compelled new engineers to form relationships with coworkers as a means to understanding what was expected of them and to help them accomplish their work. At a higher level in the organizational system (beyond the work group level), new engineers encountered additional constraints and enablers in the structure and work processes of the organization.

Working within the Organizational System

Many new engineers reported their perceptions of the affects of the organization’s culture and structure on their work. In some cases, participants compared similarities and differences between organizations because of their intern or coop experiences in other organizations or because they had a friend working for another firm. At the organizational level, new engineers described experiences related to learning the “big picture”; understanding the non-engineering priorities and decisions of the organization; and, working through cultural and systems procedures.

Learning the ‘big picture.’ An important topic for nearly all new engineers was the need to understand how their work fit into the larger organization. Often, it was difficult for newcomers to get this understanding from within the boundaries of their work group. There were only a few examples reported where managers of the work group explicitly provided an overview of how the work in the group fit into the organization. In discussing their work (especially problem solving tasks), new engineers often cited a lack of understanding of the big picture as a contributor to the uncertainty and ambiguity in their understanding of their work. Some expressed that "I had a hard time just trying to understand how the system actually worked. Even now, I'm still a little iffy on a lot of details and whatnot." and that "One of the first things is kind of like to get oriented into the actual whole system, because the system is just like absolutely, ridiculously huge."

Understanding non-engineering priorities and decisions. Other organization-level issues for new engineers involved learning the reasoning behind decisions and priorities in the organization. Learning the priorities of the organization provided important clues about the value of one's work in the organization. New engineers developed different perceptions about how valued their work was to the organization, and often these perceptions were based on the resources and attention given to projects that indicated different priority levels. Some of these newcomers recognized that, "The company has a tendency to put its best people on its money programs." Also, there are times in a project that it is "late to be changing a lot of stuff, a lot of stuff's already been sent out the supplier, we've gotten bids back on it, and we sent them back and said okay. So a lot of things can't change"

Working through cultural and systems procedures. In some cases, new engineers found the cultural and group practices counterproductive for what they perceived to be the effective resolution of problems. Often, new engineers perceived procedures as barriers or constraints to efficiency or effectiveness, although they also understood that some level of bureaucracy was inevitable in a large organization. New engineers generally perceived the cultural, group, and procedural qualities of the organization as "necessary evils" or impediments for effective engineering work, "when I do things on my own and I grab people and we try to figure things out, we make the plan and everything smooth. But when people are sticklers of the process, you run into a lot of problems."

Summary of Working within the Organizational System.

New engineers in this organization often struggled with what they perceived as excessive and counterproductive complexities and inefficiencies in organizational procedures. Yet they also seemed somewhat resigned to the fact that it was necessary to have these procedures as a means to alleviate problems and require more rigorous documentation. This acceptance of procedures was characteristic of how new engineers accommodated themselves to the organization.

Managing Individual Effort.

Along with interacting with coworkers, new engineers also described their efforts to manage their individual performance on the job. Many of these descriptions identified the skills new engineers perceived they needed to apply or develop to accomplish their work and advance their careers. By managing their performance, new engineers reported that they wanted to: (a) actively gain experience to increase their expertise, (b) become intimately familiar with their job, (c) meet and exceed the objectives set for projects, and (d) contribute value to the organization.

Differences between Engineering Practice in School and the Workplace

One of the final questions asked of new engineers in this study was to describe the differences (if any) between how they perceived engineering practice when they were in school and how they perceived it now after several months on the job. There was a wide range of opinion about the value of their education for work. Some clearly described learning concepts they needed on the job and others made little to no connection between what they learned in school and what they were doing on the job. In one case, the new engineer described both extremes. For example:

> Almost everything you do here, you fall back on what you've learned in school ... Because you're doing engineering, when you run into a problem, you'll say -- oh, I remember, I learned this concept in this class or this. Or we worked with, we learned a lot about this for however many months. You fall back on it, but it seems like you have to learn everything on the job and if you had the aptitude for it you could probably just start... You wouldn't need the college, you could just start and learn it. Over the four years of working, you could have almost learned the same things you would have learned in school.

> Like honestly, I don't feel that other than like my math and my computer skills, I haven't really had to do engineering in my opinion. I guess figuring out how -- I try to use some deductive reasoning and stuff like that, but I don't feel like I've had to actually do engineering.

> Whereas in real life, right, you're not going to just bend the thing, see what happens and explain it, and then move on to your next assignment. You're going to bend that thing, see what happens, explain it, and try and fix it. Whereas in school, you explain it and get a result and then no follow-up.

It seemed that many of the differences between the expectations new engineers reported having in school and their experiences in the workplace depended on the nature of their work in the organization. Some described their work as largely comprised of project management and data management. Others described more focus on problem definition and problem solving. New engineers having assignments that involved more problem-solving skills reported more relevance to their education, yet there were notable differences between the problem-solving experiences reported in school and those reported in the workplace.

> I guess in school you've got your specific material you're learning and you have your specific problem that goes with that material. In real life you never have anything that specific, at least with my experience so far. I'm sure there are some people that do, but then they'll only have those kinds of specific problems. Mine, I have to combine that with 500 other specific problems that we might have done in school. It's never just that one focus.

> I think that was maybe one of the one big differences between . . . my experience at school and what I wound up working on here is that at school you try and *understand* everything. And when you're in the research lab, your goal is to *explain* everything. . . . So here it was kind of -- you have a project that 10 or 15 expert people with experience are working on and they don't understand everything. So I mean there's no way that one person can kind of understand every little thing.

> I think school was more like a technical thing, like where you learned equations. Where now it's more like a logical sort of brainstorming, think through stuff, you know, sort of thing. It's more of a hands-on thing where you kind of see it and you're taking measurements or taking a part on and off. Or you know it's not fitting right but you don't know why and there's no mathematical formula you could use like you would in school to solve this problem kind of thing.

Generally, new engineers stated that they learned a "way of thinking" in school that helped them define problems, handle and evaluate data, and make decisions based on these data. What seemed to be missing in their education were the moderating effects of the social and organizational systems, as well as higher levels of complexity and ambiguity inherent in real world problems.

Summary of Findings

Table 1 displays a summary of the work experiences emerging from the data in this study. While new engineers primarily defined their work as a problem-solving process, they also described the extent to which this process was embedded in social and organizational structures and processes. Thus, their work as problem solvers was mediated by the social processes, procedures, systems, and culture of the work group and the organization.

Table 1. *Categories of work experiences for new engineers.*

Categories of Work Experiences	**Work Experiences**
Problem-Solving Process	Organize, define, & understand the problem. Gather, analyze, & interpret data. Document and present results. Manage the overall problem-solving process.
Working within the Group (social system)	Develop relationships with others Learn from others. Collaborate with others. Influence others.
Working within the Organizational System	Learn the 'big picture.' Understand non-engineering priorities and decisions Work through cultural and systems procedures.
Managing Individual Effort	Gain experience to increase expertise. Become intimately familiar with job and data. Effectively manage efforts to exceed objectives. Contribute value to the organization.

A common theme emerging from these data indicated that problem solving was a more complex process than what these engineers reported they experienced in school. Also, the enormous influence of the social context was the primary difference between school and the workplace.

Overall, these data indicated that the social context was a primary mediator of the experiences of new engineers in this organization.

To make a successful transition from school to the workplace required new engineers to integrate effectively into a work group by developing relationships with coworkers and managers. Without effective, high-quality relationships with coworkers and managers, new engineers struggled to learn what they were to do and how they were to do it. Hence, the quality of their relationships on the job had an enormous effect on the quality and success of their learning.

5. Discussion

This analysis began with data collected from new engineers' responses to questions asking them to describe a specific problem or project to which they were assigned shortly after starting their new jobs. Further questioning asked them to describe their experiences and processes for working on the problem or project. Four categories of work experiences emerged from a content analysis of their responses. Table 1 provides a summary of the four categories and of the work tasks composing those categories.

What is not apparent from this table is the interdependency of these tasks. For example, defining a problem often reflected the presuppositions, preferences, and expectations of others in the group, along with the acceptable procedures and structures constituting the organization. The methods participants followed for working on a problem or project depended on instruction and guidance from coworkers and managers reflecting the preferences and expectations of others in the organization. The complexity and ambiguity of some of the problems reported by the new engineers in this study agrees with the descriptions of ill-structured problems provided by Jonasson, Strobel, and Lee[46]. They characterized the everyday problems of engineering as ill-structured, having multiple, often conflicting goals and multiple solutions. Furthermore, non-engineering constraints and standards bound these problems into the cultural context of the workplace. While some of the new engineers in this study described their assignments as ill-structured problems, much of the work also entailed routine data gathering, organizing, analyzing, testing, and reporting. Most of their work involved collaborating and coordinating with others.

During the socialization process, new engineers often started with low-level, low-risk assignments described as a method to orient the newcomer to the work, teach them how to use the tools, or because the work group was unprepared for anything else. Some newcomers reported weeks not having anything but "busywork" with little interaction with coworkers. However, in most situations, new engineers depended on others to show them what to do and how to do it. This dependency on others to accomplish one's work required that the new engineer develop good relationships with others and adhere to the constraints of the procedures and culture of the organization.

In many situations, coworkers or managers of the new engineers framed an assignment for the newcomer as part of the socialization or learning process. Typically, others having more experience in the organization defined the problem and assigned specific tasks to the newcomer. Also, as questions arose during the execution of these tasks, newcomers sought feedback from experienced others. In this way, the process of problem solving was embedded in the legacy of work group's subculture, systems, processes, procedures, and the expectations of others.

Many of the new engineers professed beliefs that applying scientific, mathematical, and technical procedures to solve problems was the essence of 'real engineering' work. Yet, the actual work they were doing depended on successfully interacting with others and attending to the demands of the social and organizational systems. There was a discernable feeling among a few of the new engineers of diluting "pure" engineering work with the "necessary evils" of organizational processes and people in non-engineering roles.

During the socialization process in this organization, new engineers were dependent on others for help in problem solving. Social cognition and social exchange explain how the influences of others determine how newcomers learn and what is learned. The reciprocally determined outcomes of socialization depend on the mutual interactions between the individual, the social group, and the environment[22]. In this study, these correspond to the new engineer, his or her coworkers and managers, and the organizational systems and culture. Essentially, how and what new engineers learned through socialization about practicing engineering was heavily influenced by the social and organizational systems in which they worked.

A challenge for many new engineers was evaluating the accuracy of their methods for problem solving—in the context of the organization or work group. The criteria for evaluating accuracy often depended on the judgment of other engineers, non-engineers, and the environment and culture of the workplace. A few engineers explicitly wondered why the answer could not derive from these data without the distractions of personalities, personal preferences, and business constraints. As one new engineer put it, we are not dealing with a dozen variables in this model as we did in school, but with hundreds of variables—many of which cannot be identified or defined.

Heywood[7] cited several authors proposing that present and future engineers needed greater flexibility and interdisciplinary skills to include factors beyond technology, such as social, organizational, and human factors. The portrait of engineering work reported in this study involves complex interactions among technical, organizational, social, and human factors. The portrait of engineering work described in this study is not a singularly technical process for problem solving. Problems come and go not only because they are resolved, but because they may gain or lose importance due to financial, personal, or market conditions affecting the organization or work group.

In summary, the reports of work experiences by new engineers in this study exemplify the important impact of the social and organizational systems on the work of engineers. These reports also suggest that many of the new engineers did not anticipate this high level of social and organizational influence on their work. The multiple and varied factors that comprise engineering work reported in this study indicate a gap between educational experiences primarily focused on developing science and math expertise and the work these educational experiences were intended to support. While school cannot prepare individuals for every contingency, it seems there are opportunities for narrowing the gap between engineering education and practice.

6. Implications for engineering education

Based on these findings, there are important implications for engineering education and the workplace. First, the social context of engineering in the workplace is a major driver of engineering work. This suggests that engineering programs might better prepare students for the social context of their work and organizations might manage the social context of the work group to help new engineers better integrate into the organization. Second, the problems faced by engineers in practice are extremely complex, ill-structured, ambiguous, and dependent on the social and organizational contexts. Educational programs that emphasize the ill-structured nature of problems in practice might provide better preparation to students. Third, there is a fair amount of routine, procedural work required of employees in organizations not related to their engineering expertise, although this varies by job. Several new engineers reported that they were not doing engineering work (even up to two years after beginning their jobs). Education might do a better job preparing students for this aspect of the work, however, organizations should have a better understanding of the work for which they hire engineers.

Problem-based learning (PBL) and cooperative learning are two pedagogical practices that have been promoted by engineering educators to increase the efficacy of engineering education[47, 48]. If done well, both pedagogies provide students with more experience in the social context of learning, which might arguably correspond more closely to workplace conditions. The participants in this study that had experience with these pedagogies reported that these experiences provided valuable insights useful for their jobs, although many participants criticized their experiences on senior design projects and teams in school as too simplistic and irrelevant to what they experienced on the job. Smith et al. stated that assigning students to projects and teams did not guarantee higher-quality learning—it was the quality of the interactions and experiences in the project or team that made them successful or unsuccessful. Learning strategies must maximize social cooperation, collaboration, and interdependence among students to effectively prepare them for the workplace.

While it seems critical for engineering education to offer industry-relevant learning experiences to students, it is just as critical for organizations to facilitate successful transitions into the workplace after graduation. The final experiences of socialization take place in industry and therefore, only industry can facilitate the final stages of a successful transition from school to work.

7. Conclusions

While this study focused on the experiences of new engineers in one organization, they cam from a variety of schools and reported a variety of work group experiences—from high to low quality. The nature of the work they describe suggests that engineering programs could improve significantly with greater emphasis on complex, ill-structured problems and the dynamics of problem solving embedded in fickle social contexts. Equally important, organizations can better manage the socialization process to help new engineers make the transition from school to work more successfully. Even the best preparation in school might not be enough to overcome dysfunctional work group practices and unproductive social interactions stemming from current employees in the work group toward the new engineer. The new engineers reporting the most difficulty and frustration with their jobs generally described their work groups as non-collaborative, uncooperative, or even hostile places. Done correctly, problem-based learning and cooperative learning help to better prepare students for the complexities of the workplace; however, the most important experiences for new engineers seem to be the experiences they encounter during the first several months on the job. At this point, it is up to the organization to facilitate successful transitions for new engineers.

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