Article

Examining the Setting of Significant Learning Events during the Engineering School-to-Work Transition

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Abstract: The school-to-work transition is a critical time for engineers that involves rapid learning across multiple fronts, but relatively little is known about the setting (i.e., how, where, and with whom) of significant learning experiences during this time. The purpose of the study is to examine the setting of significant learning events for recent engineering graduates. We used a multi-case study in which 12 recent engineering graduates responded to weekly reflective journal prompts for the first twelve weeks of their transition from school to work. Participants described significant learning events through a series of open-ended questions. We used both deductive and inductive coding to identify the setting of the event in terms of how, where, and with whom engineers engaged in learning at work. The findings highlight the emergent, social nature of workplace learning and point to critical differences across school and work. To better prepare students for professional practice, engineering educators should consider how they might create learning environments that promote effective transfer of knowledge and skills.

Keywords: engineering practice; engineering education; school-to-work transition; qualitative methods

1. Introduction and Background

Engineering practice and the school-to-work transition are important to understand to prepare graduates more effectively for the realities of modern engineering practice. While a number of studies have explored differences between engineering school and engineering work [1–4], less research has explored the setting of learning at work and the contexts in which newcomers engage in learning. The school-to-work transition remains a persistent challenge for new engineering graduates, with reports highlighting gaps in a range of different areas that are vital to effective professional practice [5–9]. During the initial period of this transition to engineering practice, recent graduates encounter a range of unfamiliar experiences, and how they navigate and learn from those experiences can impact job success, satisfaction, commitment, and performance [10,11]. It therefore is important to support students and emerging professionals in ways that can best prepare them for the realities of engineering practice.

To date, we know relatively little about how new engineers experience learning as they transition from school to work [12]. Some research focused on perceptions of preparedness [13], skill relevance [14], and the role of social exchanges [15], but less research has focused on the setting of learning experiences—i.e., how, where, and with whom learning happens. Nonetheless, existing research points to the importance of context in learning and points to the need to better understand the ways newcomers engage in learning as they transition from student to professional. Understanding the settings in which new engineers learn during this period can help engineering educators and industry professionals identify strategies to better support individuals as they transition from school to work and gain professional competence. The purpose of this work is to explore the

setting (i.e., how, where, and with whom) of impactful learning experiences for recent engineering graduates during the first 12 weeks of the school-to-work transition.

The need for this work stems from critical contextual differences between school, where learning is the central goal, and work, where learning, while often necessary, is typically undertaken in the context of job performance. In a typical academic context, students' goals are driven by the need to acquire knowledge and demonstrate proficiency for an evaluator (e.g., on a test or homework assignment). At work, the goal of a given activity might be to advance a project, finalize a design decision, improve profitability, or any number of activities in which learning is a means to an end. Further, in moving from student to professional, engineers must interact with and learn from diverse groups of peers, colleagues, clients, and supervisors in ways that often differ significantly from the types of interactions they likely experienced in academic settings [16,17]. Put another way, conditions and tasks that prompt learning at work are often rather different from those students encounter in the bulk of their technical engineering courses.

More recently, communities have emerged around research on engineering practice, in part due to concerns about engineering graduates' preparedness for the workplace. Within this research, there is often an emphasis on recent engineering graduates [18]. For example, Lutz and Paretti (2021) explore the role of social and cultural learning during the school-to-work transition and show how engineers engage with both technical and non-technical learning [7]. Further, Paretti, Ford, Kotys-Schwartz, Howe, and Ott (2022) highlight challenges in managing interpersonal interactions and point to the need for greater attention to relationship management skills beyond senior design courses [19]. This same project also examined the transfer of communication skills from school to work and noted challenges that stem from inherent contextual differences across school and work and the situatedness of effective communication practices. The research points to the need to better understand the contextual elements of engineering skills in ways that can better facilitate their transfer from school to work. Jesiek, Buswell, and Nittala (2021) used participant narratives to explore dominant themes in early career engineers' experiences and further emphasize the importance of communication in boundary-spanning activities (i.e., where engineers must work with people from other disciplines, ways of thinking, etc.) [20]. What is notable about this recent work is that the findings all highlight the stark contrast between the kinds of learning that engineering students engage in at school and that experienced in the workplace.

These differences are critical because they imply that, among other changes associated with the school-to-work transition, new engineers must learn to learn differently and in new contexts. Here, context applies to the physical setting, as well as the culture, time, people involved, organizational goals, and related factors—this context both constrains and enables different kinds of learning [21,22]. Reports from researchers, professional organizations, and industry suggest that engineers will continue to learn throughout their careers, especially as the learning environment changes markedly [23].

For this study, we wanted to better understand the setting and context in which learning occurred during the school-to-work transition. We conducted an exploratory study around significant learning events for recent engineering graduates and addressed the following research question:

What are the settings of significant learning events during the school-to-work transition for recent engineering graduates?

This work builds on research by Lutz (2017) who explored the initial phases of the school-to-work transition for mechanical engineering graduates [24,25]. Here, we refine the process for describing the setting of different learning events that were not accounted for in prior analyses. We use this analysis to draw contrasts across the learning environments reported here and those common in undergraduate engineering programs. Considering these differences across school and work, we offer suggestions and implications for engineering educators to better prepare students for the realities of practice.

2. Materials and Methods

The study presented here is part of a larger, longitudinal multi-case study of the school-to-work transitions of newcomer mechanical engineers, conducted with approval from the Virginia Tech Institutional Review Board. We employed multiple forms of data collection and each case included three forms of data. Here, the present research focuses on findings from weekly journal prompts because they represent discrete accounts of significant learning events suitable for analysis.

2.1. Sample

Students were recruited during the spring 2016 term from the graduating class of mechanical engineering. We sampled students from mechanical engineering for two reasons. First, the industry-focused nature of the field makes it a useful site for exploring the school-to-work transition of bachelor-level graduates (i.e., many graduates enter industry as opposed to graduate programs or alternate industries). Second, as one of the largest engineering fields nationally and the largest major at the study site, it afforded an opportunity to obtain a larger and more diverse sample to better support theoretical replication along both demographic and employment variables. Table 1 summarizes participant demographics by race and gender. Table 2 summarizes company size, industry sector, and prior work experience for each participant.

Table 1. Participant demographic breakdown.

Race/Ethnicity	Gender (Self-Identified)	
	Male	**Female**
Non-Hispanic White	6	1
Non-White	3	2

Table 2. Overview of participant workplace characteristics and experience.

Pseudonym	Company Size *	Industry	Prior Experience	With Current Employer?
Eric	Large	Aerospace	Co-op	No
Jimmy	Large	Aerospace	Co-op	No
John	Large	Manufacturing/Maintenance	Internship	Yes
George	Large	Manufacturing	Co-op	Yes
Jeff	Large	Nuclear	None	N/A
Eddie	Large	HVAC	Co-op	No
Carrie	Large	Automotive/Industrial	Co-op	Yes
David	Large	Aerospace	Internship	Yes
Sheryl	Medium	Regulations?	Internship	No
Bonnie	Medium	Construction Management	Internship	Yes
Kurt	Medium	Maintenance Engineering	Internship	Yes
Doc	Small	Consulting	None	N/A

* Large = over 1000 employees: Medium = between 100 and 1000 employees; Small = less than a hundred employees.

The preponderance of prior work experience is noteworthy in terms of its potential influence on the study. Participation in internships and co-ops can provide technical and social resources that a newcomer might not possess. Research has shown that co-ops can enhance newcomers' understanding of their role and provide initial knowledge needed to support a smoother transition [26]. Further, newcomer learning is facilitated through social interactions, and newcomers with existing social capital might more effectively leverage these resources (e.g., working relationships, professional networks) to support their learning.

2.2. Data Collection

Data were collected via weekly reflective prompts. Each week, participants responded to a series of open-ended questions via email that asked them to reflect on their biggest challenge; most important thing learned; or most significant accomplishment, along with prompts to elicit details about the experience, as illustrated in Figure 1. The use of email (in contrast to a survey collection tool such as Qualtrics or Survey Monkey) created a dialogic environment and offered the ability to follow up with participants to ask for clarification and probing when needed.

Think about your experiences over the past week. Your answers do not necessarily need to be related to events that occurred during official work hours, but should be related to your experience transitioning from school-to-work.
1.   What was your biggest challenge this week?
2.   What made it so challenging?
3.   How did you approach this challenge?
4.   Did anyone else play a role or help you with this challenge?
5.   What would you do differently next time?
6.   How do you see this relating to your undergraduate experiences?

Figure 1. Example reflective journal prompt for a significant challenge.

Participants were sent these questions, or similar variations for the first 12 weeks of their jobs. Other prompts replaced "biggest challenge" with "most significant accomplishment" or "most important thing learned/realized". Prompts were rotated weekly.

We collected data for 12 weeks because prior research has shown that one's first 90 days on the job can significantly influence subsequent performance and integration into the organization [27]. Probing about key moments in these ways provided a space for participants to unpack significant learning moments as they occurred each week. Out of a possible 144 journal responses (12 participants for 12 weeks), 129 journal prompts were completed and returned (~90%), with all but one participant returning at least 9 out of 12 and all but three returning at least 11.

2.3. Data Analysis

Analysis was iterative and used both deductive and inductive coding. Journal entries were coded following Miles, Huberman, and Saldaña (2014) [28], starting with the framework proposed by Jacobs and Park (2009) as the basis of an a priori descriptive codebook [29]. However, we expanded our codebook to capture nuances and variations not accounted for in the initial model.

Framework

Most discussions of workplace learning describe learning as either formal or informal. And while that is often a useful way to think about the different kinds of learning at work, it limits the description of finer-grained aspects of that learning. We therefore sought a framework that could describe learning conditions with more precision. We selected a framework proposed by Jacobs and Park (2009) as our starting point because it offers a more specific way to characterize the diverse modes of learning that newcomers can engage in. Their framework, shown in Table 3, defines the conditions of workplace learning along three dimensions: (1) location, (2) degree of planning, and (3) role of facilitator. Location primarily distinguishes experience-based learning from dedicated training environments. Planning describes the structure and intentionality around a learning event. Facilitator helps to describe the role of other people in learning events.

Table 3. Dimensions of learning conditions as proposed by Jacobs and Park (2009, p. 144–145).

Dimension	Category	Definition
Location	Off-the-job	Learning occurs away from where the actual work is done
	On-the-job	Learning takes place near or at the actual work setting and through typical work tasks
Planning	Structured	Evidence of a systems approach, intentional learning outcomes and assessments
	Unstructured	Little to no evidence of a systems approach, no specific learning outcomes or assessments
Facilitator	Active	Facilitator engages learner and plays a direct role throughout the learning process
	Passive	Facilitator plays a limited role during the learning process; newcomer engages others as needed

These categories served as a priori descriptive codes for data analysis. The analysis was iterative, with multiple rounds of review by the authors as well as trusted peers. Throughout this analysis, additional categories emerged from the data, and definitions of existing categories were refined to better describe the settings reported by participants in this study. Table 4 lists the final codebook; note that for two of the three dimensions (structure and facilitation), we added a third category based on participants' reported experiences. The full discussion of these codes appears in the Results section.

Table 4. Final operationalized codebook to categorize learning events.

Setting Variable	Operational Definition
Location	Degree to which learning takes place under typical workplace circumstances and contexts
On-the-job	Learning event that takes place under typical work circumstances and contexts. Experience- as opposed to instructional-based learning events.
Off-the-job	Learning event that takes place outside typical workplace contexts or that is done under circumstances outside of regular workplace activities.
Planning	Degree to which a learning event has structure, as defined by evidence of planning and intentional teaching efforts toward the newcomer
Structured	Learning event that was BOTH planned in advance AND designed to provide education to the newcomer.
Unstructured	Learning event that was NEITHER planned in advance NOR designed to provide education to the newcomer.
Semi-structured	Learning event that was EITHER planned in advanced OR designed to teach something to the newcomer.
Facilitator	Describing the role of facilitators in learning based on who instigates and sustains or drives the experience
Active	Learning event in which external facilitator initiates and drives the learning experience.
Passive	Learning event in which the newcomer initiates and guides the learning experience.
Balanced	Learning event in which the newcomer and external facilitator work dialogically together to initiate and drive the learning experience.

2.4. Credibility and Trustworthiness

To support the credibility and trustworthiness of this work, we implemented two strategies: member checking and intercoder agreement. We conducted member checking in three ways. First, the journal methodology allowed member checking to be an ongoing process in that Author 1 followed up on individual journal responses to ask for clarification as needed. Second, during week 7, Author 1 provided all participants with a preliminary interpretation of their experiences thus far. Participants reviewed this summary and responded to confirm, modify, or add to it. Finally, the follow-up interviews provided a

member check by giving participants opportunities to elaborate on and clarify the journals they composed throughout the study.

We accomplished intercoder agreement through a series of three steps. First, both authors discussed each criterion and sample journal excerpts, along with different passages from the 3-month interviews as needed, to develop the operational definitions of the codebook. After the definitions were finalized, another researcher reviewed journal entries within each category to ensure the internal consistency of each setting code. Lastly, journal entries were coded by another independent researcher, and results were compared across coders. In all phases, disagreements and discrepancies were argued to consensus, and codes were refined.

2.5. Limitations

Several limitations guide the interpretation and transferability of the findings. One limitation is related to the manner and timing of the sampling and data collection. Participants in our study were recruited during the middle of the spring semester prior to graduation and needed to have secured employment at the time of the screening survey. This means that most had prior work experience (i.e., co-ops or internships), and even those who did not, by virtue of having secured early employment, were potentially higher performing (e.g., higher grades, deeper professional networks).

Second, the journal prompts captured only one experience or event per week. The data set does not include other learning events throughout the week and it is therefore possible that participants had multiple significant experiences and had to choose one to reflect on only one. Moreover, these results do not represent the only learning that newcomers experienced, or even their predominant mode of learning. Instead, the findings help identify the learning experiences participants perceived as in some way most significant each week. While significant events likely went unreported, our data collection approach nonetheless probed for detailed information related to single impactful events in ways that offer rich descriptions of learning.

Last, the methodology used (i.e., weekly journaling) is potentially an intervention itself. By asking participants to reflect on their week—an activity they might not have done on their own—we changed the way they experienced their school-to-work transitions. In many cases, the effect was positive on participants and was not perceived as a burden, but the fact that participants knew they would have to recall and reflect on an important learning event each week likely altered the ways they experienced and moved through this time period.

3. Results

Our research question asked, "What are the different settings in which significant learning events occur for engineers during the school-to-work transition?" We used a framework laid out by Jacobs and Park (2009) as a starting point and expanded our codebook to account for our emergent findings. Participant responses highlight the diverse settings in which newcomer engineers learn to perform their new jobs during the first 12 weeks of work. In terms of location, most learning occurred on the job in order to accomplish a work task, though participants also reported significant learning off the job through short courses and training. In terms of structure, participants described learning in settings with varying levels of planning and organization and highlighted the often-emergent nature of learning activities at work. Regarding the role of facilitators, our findings demonstrate diversity in terms of both the kind of facilitator (e.g., office mate, supervisor, and HR rep) and the role they play in significant learning events. The following sections will highlight examples and offer some nuance for each code through participant quotes.

3.1. Location

Location refers to the degree to which a learning event occurred as part of a normal work task. Participants frequently described learning through the completion of work-specific tasks. For example, Jimmy described learning related to working on a portion of a grant proposal.

> *The biggest challenge this week has been working on this proposal I was assigned to. It has been challenging because I'm not getting any support from others. All I was given was an equivalent of a research paper and told "Go write these two things for the proposal". I've had to make a bunch of phone calls and sit through some meetings just to get the basic information I needed. It also doesn't help that this is week 3 and I only know a handful of people to begin with.* [How did you approach this challenge?] *I approached it by asking a lot of questions.* [. . .] *I've just found that sometimes people can't help unless you ask the right question, but sometimes you don't even know what to ask. It's been a Catch 22.* [Jimmy]

Jimmy describes a process of learning how to find information and engage in background research to better understand the context needed to complete a task. In this case, the learning (i.e., research) occurs as a means to accomplish a larger task (i.e., writing a grant proposal). Another example highlights on-the-job learning through preparing and revising consulting estimates.

> *The most important thing I learned this week is that in industry, money moves mountains. Money can change priorities, clients and even personal relationships.* [. . .]. *Most of our clients prefer maximum profit over environment, which sometimes does not align with my values. My supervisor made me realize this when I turned a project with the greenest solution but told me the clients were not happy. So I had to redo the work to make it more profitable.* [. . .] *In college it was always easy to find the right decision since money in the problems is fictitious. It's more complicated when you have contracts for hundreds of thousands of dollars.* [Doc]

In this example, Doc is learning how technical solutions and reports are affected by non-technical factors, and how engineering work products reflect the values of their organizations and stakeholders (e.g., "profit over environment"). This learning occurs through the completion of a work task and serves to help newcomers learn both how to do things and why they are done that way.

Off-the-job learning took place in settings beyond the typical scope of work. Most often, this took the form of short courses or training. For instance, Eddie describes his experience being sent, along with the rest of his hiring cohort from other sectors of the company to a corporate training program.

> *. . . My company flew me back east to the company headquarters for 4 days of orientation. The other 25 participants in this rotational program and I were granted an audience with a lot of the senior leadership of the business so that we could introduce ourselves and ask questions, which was cool. The most important thing I learned this week was what is expected from me in this position* [. . .] *The president and CEO of [sister company] and the CIO of [my employer] both spoke about how important it was to think about how your role fit into the goals of the company.* [Eddie]

The orientation contained presentations, panels, and networking events with other executives throughout the multinational corporation. This orientation is not within the typical scope of work and includes sessions to teach technical and professional skills relevant to the company. Participants reported learning across a wide range of contexts both through work tasks as well as formal training.

3.2. Planning

Planning concerns the structure of the event and the degree to which there are specified outcomes connected to a learning event. Structured activities had evidence of intentional

processes and outcomes. For example, some participants attended extended onboarding programs that mimicked a traditional educational environment.

> *Within [my industry], there are basically 6 big buckets of type of businesses/customers that we may see. We've been given 1 to 2 day overviews of these sectors, including the applications and products that we're most likely to see in each instance. I realized by the end of this past week, that we had finished all but one of the sector trainings.* [Carrie]

Here, Carrie attended a 12-week off-site training/orientation with the cohort she was hired alongside. The program included formal educational aspects such as timed exams and technical lectures. And while this program provided opportunities for job shadowing and hands-on training, with arguably less structured activities, they were organized and segmented in specific ways for new hires to complete rotational assignments.

Unstructured activities were events in which there was no evidence of inherent structure or intentional learning. For example, during week 1, Doc described his biggest challenge as related to getting used to his office and the adjustment to think in terms of billable hours.

> *My biggest challenge this week was getting used to the dynamic of being a consultant. In my office, we worked with billable hours, so your value is measure in how many hours you can bill to the client. Therefore, everything I do during the day has to be measure and record (every hour).* [Doc]

The event described here is unstructured because it (1) lacks any evidence of intentional teaching efforts and (2) is not planned. No one planned a specific event for Doc to prepare for the dynamics of the office, and there was no evidence of any specific educational efforts (e.g., a new employee orientation). Unstructured events reported here demonstrate the range of settings that are perceived by newcomers as learning environments. Doc's challenge noted above demonstrates how something that might be mundane to a more experienced worker can require a major adjustment for recent engineering graduates; even routine processes can be significant learning events.

Finally, an emergent dimension from this research was the addition of semi-structured learning events to the codebook. Semi-structured events were either scheduled in advance or showed evidence of intentional teaching or educational efforts toward the newcomer, but not both. For instance, Kurt discussed the role others have played in teaching him about different aspects of his job.

> *[E]veryone I've had to talk with along the way has [helped me communicate across groups]. My whole group I work in also has as well as my planning supervisor. They've just helped me see the full picture of the [mechanical part] from each perspective. One will show me how hard it is on the shop to get the job done, one will show me the cost and time delay in ordering the part. Everyone has just given me a different view.* [Kurt]

While the learning was not necessarily planned ahead of time, Kurt engaged with others in his organization who have a responsibility to provide learning experiences during onboarding (e.g., a planning supervisor). Newcomers in this study were often paired with a mentor or supervisor who was—at least in part—responsible for the onboarding and organizational education. And while their interactions were intended to teach or provide guidance of some kind, these events were not always scheduled in advance. The addition of semi-structured events helps account for the broad range of settings in which learning can occur at work.

3.3. Facilitator

This code helps to describe the role of other people in engaging or facilitating learning. Active facilitators are those who initiate the learning process, such as coworkers or mentors or supervisors. For example, Kurt described the role his colleagues have played in helping him get up to speed at work.

> *My immediate supervisor has been pretty helpful. He's given me a lot to do and also has followed up with the IT help desk often for me. My group (we are split off into different groups in my code which all work on different submarine systems, I'm in propulsion) has also been there to give me items to read through and prepare myself for when I do get access.* [Kurt]

By "giving him work", Kurt sees these colleagues as helping him better understand the context of his work while he awaits his clearance, and this engages him in learning.

Passive facilitation events are those where newcomers are the primary initiators and drivers behind the learning. The code does not represent a lack of engagement for facilitators, but rather an active involvement on the part of the newcomer. For instance, Sheryl described learning how to find information through workplace networks.

> *When in doubt, go seek help. After trying to find the answer myself for a day and a half, I should have asked for help sooner because we are evaluated on production. My trainer was very helpful and suggested a lot of things that would help me out. Pointed out areas where I could find my answer. I realized I was looking at the wrong resources (databases) for the information I needed.* [Sheryl]

Sheryl seems to spend some time alone searching in unhelpful locations, and it is not until she initiates learning with her supervisor that she finds better approaches. This code highlights the often self-directed nature of learning at work.

Finally, balanced facilitation represents another addition to the codebook. We added this code to capture the collaborative and dialogic nature of learning for participants in this study. Balanced facilitation entailed a shared initiation and sustaining of learning that took place across multiple days or weeks. For example, Eddie described a significant exchange that was initiated by both Eddie and his coworker at different times for different tasks.

> *He spent about an hour with me each day on Wednesday through Friday explaining the technical side of the work he had been doing for the last few weeks and answering all my questions. He forwarded me a document he had been working on that provided some background on the work he was doing, so I was able to read that and ask about it too. Finally, he helped me track down some samples of heat exchanger tubing that I need to take the next step in my first project.* [Eddie]

Eddie initiated the exchange because he knew his coworker was knowledgeable about the project. His coworker then devoted some time to helping, shared documents, and answered questions over a period of a few days. Balanced facilitation captures the back-and-forth nature that characterizes important instances of workplace learning.

3.4. Summary of Results

Table 5 below offers frequency counts broken down by each dimension and code. As noted earlier, however, the data do not suggest that these are the predominant or most frequent modes of learning but rather that these experiences are the ones our participants considered most important within a given week. Regarding location, most learning experiences reported were on-the-job—that is, they took place through normal workplace activities. In terms of planning, the results show that while about half of the learning reported here took place with some level of structure or intentionality, half of the experiences were totally unstructured. This suggests that even though these settings might not have specific objectives or structure, they are nonetheless perceived as impactful for learning. Finally, our findings point to the prevalence of primarily self-directed learning for newcomers. Most learning was initiated by participants or a balanced effort between them and another organizational member. These findings highlight how impactful learning can take place through tasks where learning is not the primary goal and where learning will not be directly assessed or tested. And although the learning was largely self-directed (i.e., initiated by participants), it nonetheless relied on the support of others through some kind of facilitation or collaboration.

Table 5. Frequency of different categories for conditions of significant learning.

Where		**Frequency**
On-the-job	Learning occurring within typical workplace contexts	90
Off-the-job	Learning occurring outside typical workplace contexts	22
How		
Structured	Event was both planned ahead of time and designed to teach something to the newcomer	29
Unstructured	Event was NEITHER planned NOR designed to teach the newcomer	52
Semi-structured	Event was either planned OR designed to teach the newcomer	31
Who		
Active	Facilitator-initiated and guided learning event	22
Passive	Newcomer-initiated and guided learning event	67
Balanced	Dialogic interaction with collaboration and shared direction of learning event	23

These findings stand in contrast to predominant modes of learning in an undergraduate program, where most experiences are designed for the purpose of learning and evaluation or learning as well as largely directed by instructors.

4. Discussion

Our findings highlight two notable aspects of engineers' learning during the school-to-work transition. First, participant reflections highlight the role of emergent, self-directed learning in driving newcomer development. Learning reported here primarily took place in ways that were motivated by work tasks and that were not designed to explicitly teach something. Second, our results also illuminate the role of social exchanges and interactions in supporting newcomer learning. Significant learning events largely took place with others and in ways where collaboration and cooperation were essential to the learning process. Coworkers, supervisors, and other organizational members are vital to scaffolding learning for new engineers. These themes point to important differences between learning at work and learning at school, and attending to these differences can help educators better understand and describe critical differences across learning at school and learning at work.

4.1. Learning as Emergent

Learning at work is *emergent*. Emergent learning emphasizes the *location* of learning and the *planning*; here, that means it took place in settings where the structure and outcomes of the activity are shaped by workplace demands. Emergent learning stands in contrast to activities in which learning is the goal and is planned, as is common in much of the undergraduate curriculum. Participants described learning as they worked to accomplish a specific task or produce a deliverable and their reflections highlight how learning is situated within broader systems and influenced by a range of contextual factors.

The preponderance of reflections coded as on-the-job helps to illustrate this point. Participants were focused on completing a project, solving a problem, or similar tasks in which knowledge was a tool, not a goal. These findings echo those from Jonassen et al. (2006), Stevens et al. (2014), and others regarding problem solving in practice, highlighting how differences across environments influence practice and learning [3,17]. Where school is often structured around planned learning events and assessed through standardized measures, workplace challenges reported by participants were often absent such planning or formal evaluation. Rather, learning occurred as part of the work, and the success was evaluated in terms of the overall success of a project or effort (which might not be immediate or easily observable). These findings echo themes related to situated learning,

where knowledge is dependent on context and acquired through authentic engagement in practice.

These findings also highlight the emergent nature of engineering practice more generally, where problems are shaped by a diverse range of forces and can change based on both technical and non-technical factors. In practice, this means that there is a wide range of job tasks that can be stages for significant learning. For example, as participants created documents and revised reports, they also learned about how to communicate their findings to engineers and non-engineers. Participants also engaged in boundary spanning, often producing deliverables for diverse stakeholders within their organizations. Researchers have noted critical differences in how engineers are prepared to communicate with others and how they actually communicate at work (e.g., Paretti (2008)), and these findings offer some concrete examples of how these context gaps create challenges for communication. and provide support for prior research [2]. This kind of learning primarily described by participants arose from authentic engagement with daily routines and tasks, both planned and unplanned, rather than through external training or conferences. Where most learning in school is structured and standardized in many ways, learning at work often occurs without specified outcomes or receiving grades (though we do note that performance reviews are likely to occur in ways that are more formal and structured).

4.2. Learning as Social

The emergent nature of learning in the engineering workplace also underscores the significance of the way knowledge is shared and accessed within a community. Learning at work is highly social; the social nature of learning is demonstrated through the role of *facilitators*. Korte (2011) and others have examined the role of social exchanges in engineering work and our findings here also demonstrate the importance of other organizational members in facilitating newcomer learning [30]. For participants here, learning was supported by a wide range of actors within the organization, both engineers and non-engineers. And even when the learning is initiated by the newcomer (e.g., passive facilitation), it is nonetheless scaffolded by another member of the company. In this study, participants reported learning from and with many different people in response to different kinds of work tasks. The nature and diversity of social interactions at work often stand in contrast to the kinds of interactions students experience at school.

In addition to skills such as communication and collaboration, our findings highlight the social aspect of workplace learning in terms of information seeking, coordination, and synthesis. Social learning at work means both effective interpersonal interactions and understanding whom to reach out to, when to reach out to them, and what to reach out to them for. Participants in this study needed to reach out to diverse members within their organizations to advance their work tasks. They identified relevant experts and combined what they learned in unique ways suited to the task. These interactions resemble a kind of distributed cognition, where knowledge exists in the collective actions of a group, and collaboration is embodied in the creation of work artifacts [31].

In contrast, in school, students often have clear experts to consult in response to specific difficulties in specific classes. When a student is struggling with a problem in their thermodynamics course, they have an expert they can contact when they encounter specific challenges (i.e., their thermodynamics instructor). In most cases, the instructor is an active facilitator in student learning experiences. Moreover, cognition and learning are also likely to be bounded by a specific class context, and information does not necessarily interact with or depend on other classes (e.g., they would not ask their mechanics professor about their thermo questions, and vice versa). While different courses might have some overlap in terms of content and others build on prerequisites, they typically do not require students to integrate knowledge in the same ways and from as diverse sets of sources as workplace tasks do in practice. Social skills move beyond simply communication and involve the importance of social exchanges and networks in learning for newcomers.

5. Implications

A key point of the present research is to present critical differences in the contextual elements that prompt significant learning across school and workplace settings. Consideration of these differences has implications for engineering educators as they work to bridge the gap from school to work.

Because the aim of the workplace is to produce goods and services and not learning, it makes sense that engineers' most significant learning experiences often occurred within typical workplace contexts and through interactions with co-workers. At the same time, it reflects an important shift in how and where new engineers need to understand learning. Situative and sociocultural learning theories emphasize the role of context and social interaction on learning and point to the challenge of transferring learning across different contexts [22,32]. We recommend that educators work to help students understand the range of learning experiences and approaches useful for navigating the various environments in which they might find themselves. One way to accomplish this might be through increasing the use of techniques like problem- and project-based learning. These pedagogies can engage students with authentic tasks and emergent goals based on iterative analysis, modeling, and reporting [33–36].

They can also help students develop some of the vital skills needed to learn and problem solve in emergent settings that characterize workplace learning and to gather information from different stakeholder and subject matter experts. For instance, 1st-year PBL experiences might include more structure and intentional connections with diverse stakeholders, where capstone design experiences might be more open-ended where student teams must collaborate to both identify and access individuals and information vital to helping them solve their problems (e.g., other faculty, industry experts, and design standards and manuals). Engineering students' beliefs about collaboration and groupwork evolve as they move through their curriculum (Rajabzadeh, Long, Saini, and Zeadin (2022)), and so consideration of appropriate interpersonal work is important to informing designing emergent, collaborative learning experiences [37].

At the same time, it is vital to reconcile these findings alongside considerations for diversity, equity, and inclusion in engineering. Many of the learning experiences described by newcomers resemble those that might be more common in extra- or co-curricular spaces [38]. These kinds of experiences likely provide some of the emergent learning experiences that participants found noteworthy during their school-to-work transition and may therefore facilitate the development of skills that ease the transition. At the same time, however, non-traditional and underrepresented students (e.g., low SES) often face barriers to participating in these activities that others might not [39,40]. For instance, many students work part-time jobs or take care of families while they earn their degrees. Other students might not possess the social or cultural capital needed to gain entry to some of these experiences [41]. Educators should therefore work to incorporate elements of emergent learning into their courses in ways that are equitable and that more effectively prepare students for problem solving in practice.

Relatedly, learning is also supported by social capital, or access to social networks and an understanding of social norms. An important part of engineers' professional development entails acquiring a knowledge of and ability to navigate social aspects of their work [42,43]. Of note in this study was the preponderance of prior experience through internships or co-ops. These experiences likely also provided participants with substantial social capital within their organizations and enabled some of the learning documented here. If internships and co-ops are impactful experiences that provide engineering students with important skills needed for professional practice, how do educators and administrators provide these experiences in ways that help students equitably acquire social and cultural capital?

Our study also has implications for engineering education researchers interested in workplace learning. First, the journaling methodology seems useful for collecting data from participants who might be challenging to access. The school-to-work transition

is an important period to understand for engineers, but collecting data is challenging in terms of time, resources, and organizational access [44]. In this research, reflective journaling allowed us to capture significant learning experiences of twelve participants across the country during the first twelve weeks of their school-to-work transitions. The richness of responses combined with the efficiency of the method suggests that it may prove useful for researchers in other hard-to-reach groups. In more recent work, Paretti and colleagues [19,45,46] have employed the method to follow more than 60 participants from multiple universities into the workplace. This research has provided valuable insight into the school-to-work transition and the ways that educators can promote the transfer of skills and professional preparation [19,47].

Second, this study has added some nuance to the ways engineering education researchers can characterize learning environments in practice. By adding dimensions to the *planning* and *facilitator* codes, we have developed a way to describe a more diverse range of workplace learning settings and this framework can be used to inform future research. For instance, researchers could use this framework developed in Table 4 to inform observational protocols for case studies. This kind of framework could also be used to explore patterns or trends in learning across disciplines, organizations, or industries. Having a better understanding of where, how, and with whom learning occurs can help inform research in engineering education by providing a lens to describe the diversity of learning environments present in the school-to-work transition.

6. Conclusions

To better prepare students for professional practice, it is vital that we develop a better understanding of the ways learning differs across these contexts. This study examined the setting (i.e., where, how, and with whom) of meaningful learning events for recent engineering graduates. Findings highlight the ways that learning is both emergent and highly social. By emergent, we mean that learning at work is largely prompted by engagement with work tasks and the need to acquire information and skills relevant to that task. As projects and goals change, so does the learning associated with them. By social, we mean that learning is supported by and contingent on social interactions with other organizational members. As participants worked on these emergent tasks, they worked with and reported to a wide range of individuals who all supported that learning in slightly different ways. Our findings suggest that while newcomers experience learning events across a range of contexts and under many different conditions, those most frequently reported stand in contrast to those common in school. While there are limitations to the transfer of skills across these different contexts, recognizing these can inform educational choices that might help students more effectively navigate the learning and working environments characteristic of engineering practice.

Institutional Review Board Statement: The study was conducted in accordance with the Institutional Review Board (or Ethics Committee) of Virginia Tech.

Informed Consent Statement: Informed consent was obtained from all subjects involved in the study.

Data Availability Statement: Data can be made available at the request of the authors.

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