

Engineers' Situated Use of Digital Resources to Augment their Workplace Learning Ecology

Hieu-Trung Le
Information Sciences & Technology
George Mason University
Fairfax, VA USA
hieutrungle@gmail.com

Aditya Johri
Information Sciences & Technology
George Mason University
Fairfax, VA USA
johri@gmu.edu

Abstract—This Research FULL PAPER extends recent scholarship on the role of technology in workplace learning in professional engineering and computing settings. Digitization of work practices has made a noticeable impact on how engineers gain expertise and solve problems they encounter at work. In this paper we use a *workplace learning ecology* lens to examine engineers' *situated information seeking* to identify practices associated with the use of online resources. Building on a previous qualitative interview study, we developed and administered a survey consisting of 16 items to assess use of online resources across learning experiences. We found high use of online resources but with variations among the use of specific resources by field, problem, and learning goal. LinkedIn, Twitter, YouTube, Wikipedia, Reddit, and technology vendor websites were the primary online platforms used by respondents for both learning and problem-solving. Respondents placed different levels of trust in online resources. Social media, especially Twitter, was trusted least across all sources. The highest trust was placed on websites of technology vendors. Findings from this work can help create better educational content as well as pedagogical interventions that use online resources for training the future workforce.

Keywords—professional engineering, workplace learning, situated learning, learning ecology, online resources

I. INTRODUCTION

Research on the professional engineering workplace is a flourishing area of study within engineering education research [1-4]. Although a range of issues are of interest within the professional engineering workplace literature such as teamwork and collaboration, use of conceptual knowledge, and lack of diversity in the profession, a major focus of work has been on understanding how professional engineers solve problems, learn, and share knowledge [5]. Workplace learning has always been crucial within the engineering profession given the need to master complex systems that exist in the industry and to keep up with the changing knowledge base and tools required to accomplish the work.

With the digitization of the workplace, changes occurring in the engineering workplace from the perspective of learning are even more multifaceted. On the one hand, new ways of working have emerged driven by the use of technology and at the same time how engineers learn and share knowledge has also changed with the use of technology. Together, changing work practices and changing ways of knowing are creating novel learning practices that are both reified and malleable – they exist but are also continuously changing. More than any other aspect of professional engineering work it is these shifting practices that make engineering learning challenging.

The dynamic nature of engineering work and unpredictable advances in technology that bring about new ways of working and learning often makes formal educational preparation inadequate and professional engineers have to continuously learn on the job. In this paper we present an empirical study that delves deeper into the use of online resources as part of the workplace learning ecology by professional engineers. Although the use of online resources is not new, the range of resources available to workers and the different ways in which they can problem solve and learn through the use of online resources has seen a marked change in recent years. This study focuses on the different tools and technologies used and the purpose for their use but the overall paper also works towards leveraging and contributing to theory development that can guide future research and practice.

The empirical case for this study comes from the domain of Information Technology (IT), an interdisciplinary area that attracts engineers from across a range of disciplines (e.g., networking, electronics, electrical, computer, systems, industrial, cybersecurity, etc.). The IT domain is a relevant for this research as the work in the domain changes continuously and the knowledge required to address workplace challenges is learned in both traditional and novel ways. The study results not only show the importance of the use of online resources but reiterate the role of interpersonal ties within the workplace learning ecology. Through a comparison of professionals in information security and others IT sectors, a different picture of the learning ecology across contexts is also evident from the findings underscoring the importance of a more nuanced and contextual examination in the future.

II. LITERATURE REVIEW

Theoretically, the study leverages a *situated information seeking perspective* to examine the *workplace learning ecology* within the context professional engineering workplace. This joint perspective is used to study the research question: *when faced with a problem-solving challenge in the context of their work practices, what online resources do workers use?* The empirical findings delve into different aspects of this question in relation to online resources that are used as part of the ecology, how they are used, the nature of trust placed in them, and some potential aspirations of the kinds of resources that might be available.

A. Situated Information Seeking for Learning

The situative perspective views knowledge “as distributed among people and their environments, including objects, artifacts, tools, books, and the communities of which they are a part” and the process of learning itself is conceptualized as

meaningful participation in a community of practice (where practices are contextually relevant ways of doing and acting) [6-7]. There is an understanding within the situative paradigm of learning that “the constraints and affordances of social practices and of the material and technological systems of environments” shape learning significantly [6]. The situative movement differs significantly from prior approaches that have found favor among scholars of learning, such as the behaviorist and cognitive perspectives, by places emphasis on the role of the environment on an individual’s conception of knowing and how they learn. Knowledge is not something that an individual possesses or stores in the brain but is present in all that they do [8].

The situative perspective emphasizes that within cognitive practice *what* and *how* of learning are closely linked. The situation, or context, determines what people look for, how they get the information, and how they interpret the information, especially in organizational contexts [9]. These information seeking behaviors, according to [10], transcend current conceptualizations of workplace learning that divide learning experiences at work into informal, non-formal or unstructured learning. Information seeking allows a better understanding of workplaces as learning spaces [11]. To examine learning in-situ, as it is triggered in the workplace a focus on information is crucial as, invariably, information seeking is a precursor to learning [1]. In recent years, the situated learning perspective has found prominence within engineering education with an emphasis on better understanding the use of resources available within engineering settings for learning as these tools and technologies, which shape the use of representations and give access to networks [12-14], shape learning. Therefore, in conjunction with a situative perspective scholars are increasingly pointing to information seeking as a way to examine learning because in many contexts and situations, learning begins with information seeking – it is motivated by the need to know something and before something can be known, it has to be acknowledged [15-16]. The information seeking process does precisely this – it explicitly makes something unknown into knowable.

Studies of information seeking shed some interesting light on how different professionals look for information. [17] reviewed the literature on information seeking among doctors and found that converting questions to a searchable phrase can be a challenge for inexperienced searchers. In terms of the type of resources used, textbooks were used 39% of the time, followed by ‘humans’ at 25%, and computers were used on average at 13%. [15] looked at the information seeking behaviors of academic scientists and found that personal communication was the most popular source for non-scholarly information and that there has been a tremendous shift in the way information is accessed compared to before. Within information security (InfoSec), which is one of the areas in which our informants work, [18] looked at the top 10 topics that users are reading in order to learn about new security trends and topics and found that most users get their knowledge about security from stories, news articles, and web pages with security advice. When looking specifically at non-experts, [19] found that most non-experts in security learn their lessons from informal stories from friends and families. These stories impact the way they think and respond to situations that they see while online. Finally, in a study of security experts, [20] examined experts’ decision-making

during security assessments and found that experts differ from novices on how they recognize certain attack models.

B. Workplace Learning Ecologies Framework

Ecology means a system of interdependent and mutually adaptive social relationships and a metaphor of *learning ecology* is useful as it allows examination of the complexity of factors that shape workplace practices and can potentially impact learning [21-22]. Organizations create structures within which workers must lead their work-life but people do not just act within structures but through them and human agency is central to the enactment of these structures [23-24]. An ecological framework captures this nexus of learning where, “educational and labor market institutions, colleges and workplaces, interact in the generation of learning ecologies that can be experienced as transformative, adaptive, or reproductive of social inequalities [21, pg. 164].” A social-ecological approach allows for a better understanding of learning within work for professional engineering workplaces as new technologies and new work patterns, such as virtual and distributed teams, have changed the structures within which workers work and lead their lives.

The use of technology has consequences for how activities are shared, not just within organizational structures but also beyond that, and how knowledge circulates across division of labor, organizational structures, and cultures [25]. In particular, the worksite itself is not the only place of learning within the ecology. There are other social, spatial, and relational aspects that support the ecology [26]. In the ecological mode, therefore, individuals can structure their environments for learning, creating affordances that were not there before and they can tactically pursue ends that extend beyond the immediate workplace [27].

Although many aspects of professional engineering work in terms of the structure of the organization are limiting and not open to changes, there are ever more affordances for shaping the context due to the use of technology especially the ability to access online information. Therefore, if a worker has the intention, either personally motivated or motivated by their work, they can pursue their agenda and seize opportunities for learning within the workplace [27]. Especially for those in professions where the work involves use of information technology, as is the case with most engineering work, professionals can create and learn through self-created learning spaces [28].

Overall, digital technologies play a significant role in expanding and developing virtual learning spaces in ways that facilitate communication, knowledge sharing, and skills development and even transnationally. In this study we look at one aspect of learning which is defined by being self-directed and [29] have shown that fundamental components of informal learning are independent and self-driven in the sense that they entail activities such as searching independently for information and practicing without direct supervision. The activity of situated information seeking fits within the learning ecologies framework, as one part of it. It is a trigger for future learning and just in time problem solving. In the context of rapidly changing work environments, as the one studied in this research project, an ecological viewpoint supports examination of the dynamics of the different elements that shape situated information seeking of workers as they enact their work practices.

III. PRELIMINARY WORK

The study presented here builds on an interview-based qualitative study we conducted previously with 15 cybersecurity professionals [30]. In the interviews participants expressed a process-based approach of seeking information in an effort to learn. Depending on the problem they faced, professionals first mapped the requirements of what was needed to solve the problem, identified the resources that were to them available, and selected the optimal resource. This process was repeated iteratively until the need for information and learning was fulfilled. Within this framework of this information seeking, workers utilized both interpersonal and online resources, depending on the requirements and information need of each specific situation.

Overall, our preliminary work found that workers made a constructive effort to construct a learning ecology to support their practices in the workplace. To further delve into the use of online resources within that ecology, the survey-based study reported here was conducted. We wanted to verify preliminary findings and identify differences in ecology through a study with a larger number of participants. In many ways this is a mixed-method study but herein we report only on the findings from the survey study and therefore we only discuss our methods and data collection in relation to the survey study.

IV. RESEARCH STUDY

The institutional research board (IRB) approved survey was publicized through social media platforms, such as Facebook and LinkedIn, and through email announcements. Efforts were made to reach a wide audience for the survey and prior work had shown that the platforms we used were the most representative for this population without using a paid survey service that could do targeted marketing.

A. Setting

The study took place among engineering professionals in the information technology (IT) industry in a large metropolitan area on the East Coast of the United States. The first author, who also works in the industry in that area, was closely aware of the industry and professional context of the area. The sample included professionals from IT services area with one subgroup from the field of information security or Cybersecurity (referred to as InfoSec in the findings section) (N=23) and the rest from a mix of IT fields (N=36).

B. Surveys

The survey was administered online and consisted of a total of 16 questions (see Table 1). Survey was designed based on other similar surveys from author's prior work and guidelines in [31]. Questions 1 to 5 were about the participant's demographic including: gender, employment status, education status, years of experience, and field of work (information security or not). Questions 6 to 10 asked participants about their behavior related to problem-solving, including their use of resources. Questions 11 to 13 asked the participant about their behavior when learning a new topic. Finally, questions 14 to 16 focused on participants' use of specific resources such as social media for finding work-related news and updates.

Demographics Questions

- Q1: What is your gender?
Q2: What is your current employment status?
Q3: Are you currently enrolled in an education program?
Q4: How many years of professional experience do you have?
Q5: Do you currently work in a cybersecurity-related field?

Finding Solutions to a Problem

- Q6 - In a typical work week, how often do you use the following online resources in order to find solutions to a problem?
Q7: In your opinion, how trustworthy is the information provided by the following resources when trying to find solutions to a problem?
Q8: When looking for information to solve a problem, how often do you go to a colleague to ask first before using internet resources?
Q9: After consulting a colleague for information, how often do you use online resources to verify it?
Q10: You are using a search engine to find answers to a problem you are currently trying to solve. Select the top 3 factors that are most important to you when choosing the specific page that would have information that you are looking for?

Learning using online resources

- Q11: In a typical work week, how often do you use the following online resources when trying to learn about a new topic?
Q12: In your opinion, how trustworthy is the information provided by the following resources when learning about a new topic?
Q13: When looking for information to learn about a new topic, how often do you go to a colleague to ask first before using internet resources?

Use of Social Media

- Q14: How interested are you to having a method that would help provide security news and updates in an efficient and clear manner?
Q15: How often do you use social media to keep up with the latest security news and information?
Q16: You indicated that you used social media to keep up with the latest security news and information. Which social media platform do you specifically use the most for this purpose?

Most of the questions used a Likert scale and the response was assigned to a weighted scale. For questions related to how often a resource is used, the weight is: "always" is 4, "often" is 3, "sometimes" is 2, "rarely" is 1, and "never" is 0. For questions regarding the trustworthiness of a resource, the score is: "very trustworthy" is 2, "somewhat trustworthy" is 1, "neutral" is 0, "somewhat untrustworthy" is -1, and "very untrustworthy" is -2. The scoring allows the author to quantify the responses in order to get a weighted average for each response. The survey was tested with five participants to ensure that it took around 7-10 minutes to complete.

A total of 59 unique responses were collected. Of the respondents, 73% were male and 27% were female. In terms of employment status: 67% worked full time, 19% worked part-time, and 14% were not currently working. In terms of education, 34% were in a full-time degree program, 12% were in a part-time degree, 22% were participating in some form of professional learning or certification, and 32% were not in enrolled in any program at the time of the survey. About 40% of the respondents work in the information security field, while 60% worked in some other information technology related field. There is a limitation of this study in terms of small number of respondents but since this work builds on prior work where interviews were used, there is sufficient data to interpret the findings and draw reliable conclusions.

TABLE I. LIST OF SURVEY ITEMS

V. FINDINGS

A. Use of Online Resources for Problem Solving

The first part of the survey asked respondents about their use of online resources to solve problems, or finding solutions to problems, they encounter at work. The ecological aspect of resource use was captured by items related to different resources used, trust in resources, and frequency of use. The categories of resources were derived from prior study and the literature.

TABLE II. USE OF ONLINE RESOURCE FOR PROBLEM SOLVING (INFOSEC)

	ALWAYS	OFTEN	SOMETIMES	RARELY	NEVER
Vendor Websites	13.04% 3	34.78% 8	47.83% 11	4.35% 1	0.00% 0
Online Forums	17.39% 4	30.43% 7	34.78% 8	13.04% 3	4.35% 1
News Articles	8.70% 2	26.09% 6	47.83% 11	4.35% 1	13.04% 3
YouTube	17.39% 4	17.39% 4	30.43% 7	21.74% 5	13.04% 3
Wikipedia	4.35% 1	30.43% 7	30.43% 7	21.74% 5	13.04% 3
Blogs	0.00% 0	26.09% 6	34.78% 8	21.74% 5	17.39% 4
Social Media	0.00% 0	8.70% 2	30.43% 7	30.43% 7	30.43% 7

TABLE III. USE OF ONLINE RESOURCES FOR PROBLEM SOLVING (NON-INFOSEC)

	ALWAYS	OFTEN	SOMETIMES	RARELY	NEVER
Online Forums	25.00% 8	40.63% 13	28.13% 9	6.25% 2	0.00% 0
YouTube	21.88% 7	31.25% 10	34.38% 11	9.38% 3	3.13% 1
Blogs	9.38% 3	18.75% 6	50.00% 16	12.50% 4	9.38% 3
Vendor Websites	6.25% 2	12.50% 4	50.00% 16	28.13% 9	3.13% 1
News Articles	3.13% 1	15.63% 5	43.75% 14	34.38% 11	3.13% 1
Wikipedia	9.38% 3	9.38% 3	43.75% 14	25.00% 8	12.50% 4
Social Media	3.13% 1	15.63% 5	15.63% 5	37.50% 12	28.13% 9

The responses for InfoSec professionals (Table 2) were in line with findings from the interviews in that vendor websites and online forums were the most used, followed by YouTube and news articles. Social media was the least used out of the group. Responses from non-InfoSec respondents (Table 3) were slightly different, with online forums having the most usage, with vendor websites being lower on the ranking list. This difference could be because InfoSec professionals tend to be more tools-focused, so they are more reliant on the vendor for information when trying to solve problems. Non-InfoSec respondents are more likely to use more vendor-agnostic resources such as online forums, YouTube, and blogs for their problem-solving. Overall, online forums and vendor websites were the most used resources when trying to solve a problem.

The results from the survey show the overall trustworthiness for each type of resource. For both InfoSec and non-InfoSec respondents (Table 4 and 5, respectively),

vendor websites and news articles have the highest trust. Wikipedia was deemed trustworthy but lower compared to other resources. Although online forums are used quite often, they had an overall lower trust. Social media had an overall negative trust for both groups. The trust for blogs was different for each group, with InfoSec having a negative trust in blogs versus a positive trust level for non-InfoSec respondents. News articles were also much more trustworthy according to InfoSec respondents, versus a lower trust for non-InfoSec respondents.

TABLE IV. HOW TRUSTWORTHY ARE THE FOLLOWING FOR PROBLEM SOLVING (INFOSEC)

	VERY TRUSTWORTHY	SOMEWHAT TRUSTWORTHY	NEUTRAL	SOMEWHAT UNTRUSTWORTHY	VERY UNTRUSTWORTHY
Vendor Websites	30.43% 7	56.52% 13	4.35% 1	4.35% 1	4.35% 1
News Articles	13.04% 3	47.83% 11	21.74% 5	17.39% 4	0.00% 0
YouTube	8.70% 2	43.48% 10	26.09% 6	21.74% 5	0.00% 0
Online Forums	4.35% 1	43.48% 10	39.13% 9	4.35% 1	8.70% 2
Wikipedia	8.70% 2	39.13% 9	26.09% 6	17.39% 4	8.70% 2
Blogs	0.00% 0	30.43% 7	43.48% 10	13.04% 3	13.04% 3
Social Media	0.00% 0	8.70% 2	43.48% 10	26.09% 6	21.74% 5

TABLE V. HOW TRUSTWORTHY ARE THE FOLLOWING FOR PROBLEM SOLVING (NON-INFOSEC)

	VERY TRUSTWORTHY	SOMEWHAT TRUSTWORTHY	NEUTRAL	SOMEWHAT UNTRUSTWORTHY	VERY UNTRUSTWORTHY
YouTube	21.88% 7	59.38% 19	18.75% 6	0.00% 0	0.00% 0
Online Forums	28.13% 9	46.88% 15	21.88% 7	3.13% 1	0.00% 0
Vendor Websites	25.00% 8	46.88% 15	21.88% 7	6.25% 2	0.00% 0
Wikipedia	21.88% 7	34.38% 11	43.75% 14	0.00% 0	0.00% 0
Blogs	6.25% 2	56.25% 18	31.25% 10	6.25% 2	0.00% 0
News Articles	3.13% 1	50.00% 16	43.75% 14	3.13% 1	0.00% 0
Social Media	0.00% 0	18.75% 6	34.38% 11	40.63% 13	6.25% 2

Figure 1 depicts InfoSec respondents use online resources, along with the trust they gave to each type of resource. The blue graph uses scores from 0 to 4 for the overall usage, while the red line graph uses scores from -2 to 2 for the trust level.

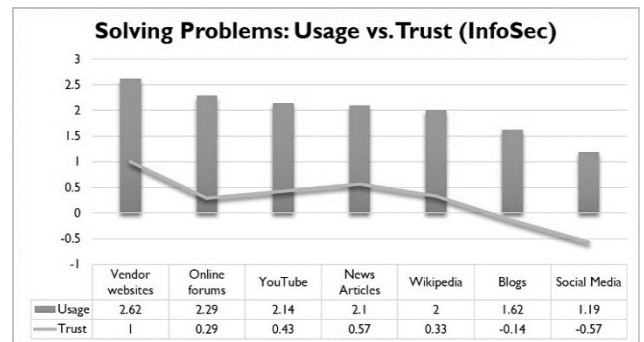


Figure 1: Problem solving and Usage and Trust of Resources (InfoSec)

B. Use of Interpersonal Resources

This part of the survey asked respondents about their use of interpersonal resources prior to using internet resources when trying to solve a problem. The survey responses show that over half of InfoSec respondents (Table 6) typically going to a colleague first, while about 30% of responding from non-InfoSec doing the same (Table 7).

TABLE VI. HOW OFTEN DO YOU GO TO A COLLEAGUE FIRST BEFORE USING ONLINE RESOURCES? (INFOSEC)

ANSWER CHOICES	RESPONSES	
Always	13.04%	3
Usually	39.13%	9
Sometimes	21.74%	5
Rarely	17.39%	4
Never	8.70%	2

TABLE VII. HOW OFTEN DO YOU GO TO A COLLEAGUE FIRST BEFORE USING ONLINE RESOURCES? (INFOSEC)

ANSWER CHOICES	RESPONSES	
Always	0.00%	0
Usually	28.13%	9
Sometimes	34.38%	11
Rarely	28.13%	9
Never	9.38%	3

In the survey, a majority of respondents from both groups said they do use online resources after they get information from a colleague (Table 8 and 9). This does not necessarily imply that professional do not trust the colleague but that could be using uses online resources to further learn and expand upon the knowledge that they learned after consulting the colleague.

TABLE VIII. USE OF ONLINE RESOURCE TO VERIFY INTERPERSONAL INFORMATION (INFOSEC)

ANSWER CHOICES	RESPONSES	
Always	17.39%	4
Usually	30.43%	7
Sometimes	30.43%	7
Rarely	17.39%	4
Never	4.35%	1

TABLE IX. USE OF ONLINE RESOURCE TO VERIFY INTERPERSONAL INFORMATION (NON-INFOSEC)

ANSWER CHOICES	RESPONSES	
Always	15.63%	5
Usually	40.63%	13
Sometimes	15.63%	5
Rarely	25.00%	8
Never	3.13%	1

C. Factors for Selecting Search Result

Professionals often use a search engine in order to find what they are looking for. This part of the survey asked the respondents to identify the key factors that influence their decision on what link to click on when choosing from search engine results (Table 10 and 11). The choices provided were collected from the interview study and the goal was to gather additional information on the top key factors. For both groups, the “organization that hosts the content” and “age of article” are the top two factors, followed by “URL/address recognition” and the “author” of the content. The “position in search engine results” seems to be more important for non-InfoSec respondents than InfoSec respondents. The “number of page views” seems to be the least important criteria for both groups. The question allowed for a fill-in response and one respondent mentioned that they just use “trial and error”, while another said they read “other user comments”, which help verify sites and info”. These responses seem to show that

each user might have a personal preference for identifying which website to use.

TABLE X. IMPORTANT FACTORS FOR SELECTING A SEARCH PAGE RESULT (INFOSEC)

ANSWER CHOICES	RESPONSES	
Organization that host the content	82.61%	19
URL/Address recognition	60.87%	14
Age of article	52.17%	12
Author	39.13%	9
Position in search engine results	39.13%	9
Number of page views	17.39%	4
Other (please specify)	13.04%	3

TABLE XI. IMPORTANT FACTORS FOR SELECTING A SEARCH PAGE RESULT (NON-INFOSEC)

ANSWER CHOICES	RESPONSES	
Age of article	87.50%	28
Organization that host the content	62.50%	20
Position in search engine results	53.13%	17
URL/Address recognition	43.75%	14
Number of page views	31.25%	10
Author	25.00%	8
Other (please specify)	6.25%	2

D. Interest in News Updates

This part of the survey asked the respondents regarding their interest in having a method that would provide security news and updates in order for them to keep up with all the changes within InfoSec field (Table 12). Overall both groups (Table 12 & 13) were “very interested” in learning more about this method, with about half of the InfoSec respondent expressed “extremely interested”. The results from this question showed that many professionals are looking for a way that enables them to stay up to date with the latest security updates, especially those that work in the InfoSec field.

TABLE XII. INTEREST IN METHOD FOR GETTING UPDATES (INFOSEC)

ANSWER CHOICES	RESPONSES	
Extremely interested	34.78%	8
Very interested	34.78%	8
Somewhat interested	21.74%	5
Not so interested	8.70%	2
Not at all interested	0.00%	0

TABLE XIII. INTEREST IN METHOD FOR GETTING UPDATES (NON-INFOSEC)

ANSWER CHOICES	RESPONSES	
Extremely interested	0.00%	0
Very interested	61.29%	19
Somewhat interested	32.26%	10
Not so interested	6.45%	2
Not at all interested	0.00%	0

E. Use of Social Media

When asked how often the respondents use social media in order to keep up with the latest security news and information, about 70% of the InfoSec respondents use it at least once per month, with some using an average of several times per week (Table 14). About 30% of InfoSec respondents

have never used social media for this purpose. Non-InfoSec respondents were less likely to use social media to keep up with security news (Table 15).

TABLE XIV. USE OF SOCIAL MEDIA FOR INFORMATION UPDATES (INFOSEC)

ANSWER CHOICES	RESPONSES	
Every day	13.04%	3
A few times a week	13.04%	3
About once a week	30.43%	7
About once a month	13.04%	3
Never	30.43%	7

TABLE XV. USE OF SOCIAL MEDIA FOR INFORMATION UPDATES (NON-INFOSEC)

ANSWER CHOICES	RESPONSES	
Every day	6.45%	2
A few times a week	19.35%	6
About once a week	25.81%	8
About once a month	9.68%	3
Never	38.71%	12

For respondents that use social media at least once per month, a follow-up question was presented to asks the specific platform they use. About 50% of InfoSec respondents use LinkedIn, with the other 50% split between Facebook, Reddit, Twitter, and other platforms (Table 16). Non-InfoSec respondents had a more even distribution between the different platforms, with LinkedIn being slightly more ahead of the other platforms (Table 17). Figure 2 shows the number of respondents that uses different types of social media platforms. The responses to these questions show that professionals do in fact use social media in order to keep up with the latest security news and information.

TABLE XVI. MOST FREQUENTLY USED SOCIAL MEDIA PLATFORMS (INFOSEC)

ANSWER CHOICES	RESPONSES	
Facebook	18.75%	3
LinkedIn	50.00%	8
Reddit	12.50%	2
Twitter	6.25%	1
Other (please specify)	12.50%	2

TABLE XVII. MOST FREQUENTLY USED SOCIAL MEDIA PLATFORMS (NON-INFOSEC)

ANSWER CHOICES	RESPONSES	
Facebook	15.79%	3
LinkedIn	31.58%	6
Reddit	15.79%	3
Twitter	31.58%	6
Other (please specify)	5.26%	1

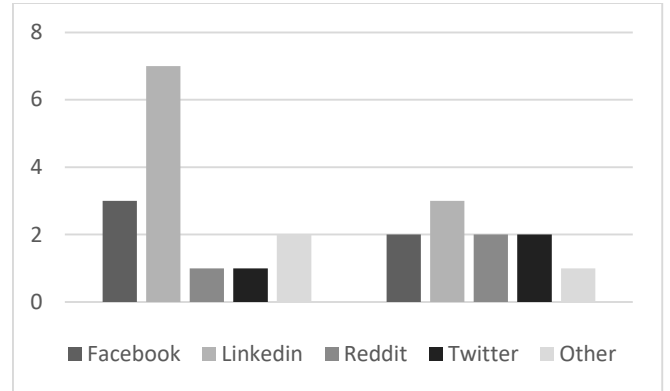


Figure 2: Social Media Use (InfoSec vs. Non-InfoSec)

F. Use of Resource for Self-Directed Learning

This part of the survey asked respondents about their use of resources for learning and their overall trustworthiness of each resource when used for learning purposes. For InfoSec respondents, the most used resources were vendor websites, online forums, and Wikipedia, with the least being blogs and social media (Table 18). For non-InfoSec respondents, YouTube, online forums, and blogs were the most used (Table 19).

When it comes to trustworthiness for InfoSec respondents, the overall trust for each type of resource when used for learning is similar to the level of trust when used for problem-solving. The most highly trusted resources for both groups were vendor websites, online forums, and YouTube. Non-InfoSec professionals have lower trust in news articles as compared to InfoSec respondents who place high trust in this resource. When asked regarding the respondent's use of interpersonal resource for learning, the responses were similar to the previous question in regard to solving problems. InfoSec respondents are much more likely to talk to a colleague first to learn about a new topic than non-InfoSec respondents. Wikipedia was used more often for InfoSec respondents, but at the same time, these respondents rated it with a lower trust compared to non-InfoSec respondents. From this response, it is more clear that InfoSec respondents prefer the use of vendor websites for both learning and problem solving, while non-InfoSec respondents prefer to use online forums and YouTube for the same purposes (Figure 3).

TABLE XVIII. USE OF ONLINE RESOURCE FOR LEARNING (INFOSEC)

	ALWAYS	OFTEN	SOMETIMES	RARELY	NEVER
Vendor Websites	21.74% 5	34.78% 8	30.43% 7	13.04% 3	0.00% 0
Online Forums	8.70% 2	34.78% 8	30.43% 7	26.09% 6	0.00% 0
Wikipedia	4.35% 1	39.13% 9	26.09% 6	21.74% 5	8.70% 2
News Articles	4.35% 1	30.43% 7	34.78% 8	26.09% 6	4.35% 1
YouTube	8.70% 2	21.74% 5	30.43% 7	26.09% 6	13.04% 3
Blogs	4.35% 1	26.09% 6	30.43% 7	26.09% 6	13.04% 3
Social Media	0.00% 0	13.04% 3	17.39% 4	47.83% 11	21.74% 5

TABLE XIX. USE OF ONLINE RESOURCE FOR LEARNING (NON-INFOSEC)

	ALWAYS	OFTEN	SOMETIMES	RARELY	NEVER
YouTube	22.58% 7	32.26% 10	32.26% 10	12.90% 4	0.00% 0
Online Forums	12.90% 4	45.16% 14	19.35% 6	22.58% 7	0.00% 0
Blogs	9.68% 3	25.81% 8	48.39% 15	12.90% 4	3.23% 1
News Articles	9.68% 3	32.26% 10	32.26% 10	25.81% 8	0.00% 0
Vendor Websites	9.68% 3	25.81% 8	32.26% 10	29.03% 9	3.23% 1
Wikipedia	9.68% 3	22.58% 7	25.81% 8	35.48% 11	6.45% 2
Social Media	3.23% 1	9.68% 3	35.48% 11	25.81% 8	25.81% 8

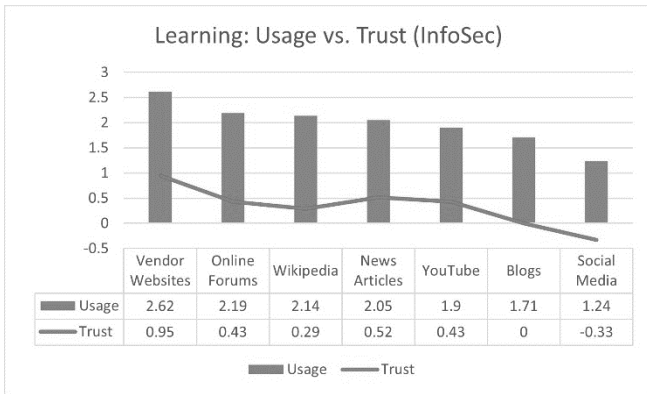


Figure 3: Resource used for learning and its trustworthiness (InfoSec)

VI. DISCUSSION

The goal of this paper has been to illustrate the workplace learning ecology of professional engineers specifically by looking at their use of online resources. Although an ecology is a complex construction and includes almost all aspects of workers' practices, in this paper the focus has been on the use of online resources. The findings of the survey show that consistent with a workplace learning ecology perspective when there is a need for situated information seeking to solve a problem, workers make use of a diverse range of online resources and their trust in these resources differs as well. Furthermore, the ecology varies among two subgroups of respondents, those who work in information security and those who work in other IT sectors. Given the need within information security for placing high trust in the information received, the use of online resources that are validated and can be trusted is critical. This could mean that while online forums may commonly be used to find solutions to a problem, their lower trust means professionals would be more likely to try and verify the information by checking other resources before using it. Overall, those working in this sector also relied less on social media for news and information.

Our prior work as well as other studies show that interpersonal interaction remains popular for workplace learning but even interpersonal learning, when it occurs, is often mediated by online technology and this is likely to be the case even more post-COVID (this study occurred just prior to the spread of the pandemic). We found differences in interpersonal problem-solving and learning within the two groups we studied and the higher percentage of InfoSec professionals going to colleagues is likely due to the relatively

"closed" nature of their work; many of the problems they face are proprietary and not discussed online. Oftentimes the challenge of looking for information online is how to actually formulate the question and search query, as putting in the wrong query could provide results that are not relevant. In the face of lack of information, it can be harder to generate a search query and find solutions online, so professionals often resort to going to their colleagues to try to find answers first. By consulting with colleagues first, professionals are able to better know what to ask for.

In terms of the ecological perspective, this study brings to light not just the use of online resources in and of themselves but the ways in which the elements that make up their ecology are extended in time and space. Online information means being able to make use of the knowledge of thousands, if not millions, of other experts who are willing to share their knowledge. It means being able to update information and learn new things almost continuously through social media and online communities where topics related to the domain are discussed. Whether triggered by a problem at work or motivated by an inclination for self-directed learning, the ecology supports workers in their learning process by extending the range of support. Consistent with an ecological perspective, this study also shows that agency is important as we find differences among participants in their use of resources. Furthermore, the context of work shaped the ecologies differently by making some resources more important, and trustworthy, than others. This demonstrates that within the larger workplace ecology perspective there is a need, as others have suggested, to differentiate among the micro, meso, and macros level factors that shape the ecology.

VII. IMPLICATIONS

Although this work has implications largely for understanding and improving workplace learning, there are several implications of this work for engineering education practice which we believe can allow for improving the college to workplace transition of students. First, this work alerts us to the resources used by professionals for meeting their learning and problem-solving goals. The use of similar resources, such as online communities (Reddit, StackExchange) and blogs, can be integrated into courses to point future professionals to novel learning resources [32]. Second, students can be asked to participate on these sites and report their participation. One of the practices that needs to be developed for the workplace is being able to find, use, and judge the veracity of resources and information and this is a good learning practice for students to develop. This exercise will also help students develop skills for self-directed learning and support navigational flexibility and autonomy [33-35]. Third, these online sources can serve as a resource for content development for many engineering courses especially where the topics change frequently. The sources not only provide access to what is relevant in the workforce but also queries and examples of problems and issues that are pertinent [36-37]. Finally, the workplace ecology concept can be used to map the learning space within an engineering program, college, or university with the use of online resources a central part of the ecology. This will help us move beyond place-based or primarily face-to-face experiences and resources that we rely on for learning and extend teaching to online or digital experiences.

VIII. CONCLUSION

This work extends recent scholarship on professional engineering settings that has shed light on the changing nature of work with increased digitization of the workplace. We use a situated information seeking lens to examine engineers' workplace learning ecology to identify their use of online resources. Findings show that online resources were used differently by professionals and even in digital information rich workplaces, other people continue to be central element of the learning ecology. The findings also show how different online platforms have emerged as a core constituent of workplace learning ecology extending the elements that make up the ecology beyond the boundaries of the organization.

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