Received 4 January 2024
Revised 8 April 2024
Accepted 23 April 2024

"Having just the right answer is almost as worthless as not having an answer": conceptualizing the information needs of undergraduate engineers

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Abstract

Purpose – This paper explores the information needs and behaviors of undergraduate engineers.

Design/methodology/approach – The paper reports on a qualitative study employing semi-structured interviews with 18 students.

Findings – The study identified the types of information needs undergraduate engineers encounter while working on problem solving tasks and the strategies they use to resolve these needs. The findings reveal that students often encounter difficulties due to a lack of procedural knowledge rather than conceptual gaps or misunderstandings. Students look for step-by-step solutions to address their information needs and become more efficient problem-solvers. However, most instructors do not provide answers or solutions, leaving students uncertain about their progress and unable to correct their mistakes. Consequently, students seek information from their peers, including step-by-step solutions and access to previous course materials. They use file-sharing and instant messaging platforms like Google Drive and Facebook Messenger as covert means of seeking help, sharing solutions and engaging in coursework-related discussions.

Originality/value – The findings enrich the theory of information needs by delineating between conceptual and procedural information needs. These findings also underscore the significant role that classmates and friends play as sources of information. The study offers implications for conceptual development of information needs, and for instructors to provide solutions and support sharing between peers on official platforms.

Keywords Information seeking, Information needs, Information sharing, Collaborative learning, Engineering education, Conceptual and procedural knowledge

Paper type Original article

1. Introduction

In this paper, I examine the information needs of undergraduate engineers and analyze how peers exchange course-related information to address these needs. While previous studies have explored the information behavior of undergraduates, particularly their approaches to accessing, seeking, and using information, questions remain about the specific characteristics of undergraduate engineers' information needs and their information interactions. The need to *know-what* and *know-how* are under-theorized in the research literature about information needs.

Picture an undergraduate engineer completing her day-to-day learning activities:

> Tina is taking a course on signal processing. She knows when and why to apply general principles and specific techniques from the course. Nevertheless, Tina is having trouble on the latest homework. For this assignment, she must identify the different notes in a musical recording. Tina needs to conduct a Fourier analysis to break the audio signal down into its basic frequencies or tones. The integration steps are complicated, and Tina is struggling with the algebraic manipulations required to obtain the final result. Tina would like to ask her instructor for help, but expects any request for a step-by-step solution will be denied. She is frustrated and unsure how to complete her homework.

This scenario is, in fact, common and drawn from the findings of this study. Motivated by the problem identified in the scenario, this paper approaches undergraduate engineers' information needs and seeking as the phenomenon of interest. I ask the following research questions:

RQ1. What are the distinctive characteristics of undergraduate engineers' information needs?

RQ2. How do undergraduate engineers address their information needs?

RQ3. What role, if any, do peers and instructors play in resolving students' information needs?

In the study, I found that undergraduate engineers frequently become stuck solving problems due to a need for know-how, rather than know-what. They seek help from their classmates because information about the problem solving process is often not available in existing classroom-based sources (e.g. instructors, textbooks, discussion forums). I explored how students use file-sharing and instant messaging platforms, in particular Google Drive and Facebook Messenger, to work around these limitations and resolve their information needs.

I begin this paper by reviewing the literature on information needs and the information-seeking behaviors of undergraduates. Following that, I offer an overview of the theoretical foundations of activity theory. I then describe the research design, including the specifics of collecting and analyzing the interview data. I used thematic analysis to interpret the responses, and produced two themes, which I subsequently present. Moving forward, I discuss the information needs of undergraduate engineers and how they collaborate on coursework. Lastly, I provide a conclusion that highlights both the contributions and limitations of the study, while also suggesting potential avenues for future research.

2. Previous research

2.1 Information needs

The concept of information needs is central to library and information science, and describes the very conditions characterized in the scenario which opened the paper. This area of research describes how people experience these problems and act in ways to resolve them using documents and information systems. Several notable scholars, including Taylor, Belkin, Dervin, and Kuhlthau, have made significant contributions to understanding information needs. Taylor's (1968) work explores the development of information needs from an initial recognition to seeking assistance from information professionals or systems. Belkin (1980) focuses on the "anomalous state of knowledge" that triggers an individual's realization of their need for information. Dervin (1992) emphasizes knowledge gaps that require information to be bridged, highlighting the assumption in the theorizing of information needs and seeking that information is the sole means of addressing these needs. Despite its significance in information seeking activities, the concept of information needs remains somewhat ambiguous (Borlund and Pharo, 2019; Naumer and Fisher, 2017; Savolainen, 2017). Wilson (1981) suggested replacing the term "information needs" due to its inherent ambiguity.

The information behavior literature often approaches information needs from a cognitive perspective, linking needs to existing knowledge structures associated with a particular topic (Naumer and Fisher, 2017). Belkin, Dervin, and Kuhlthau, among others, argue that information needs arise from gaps in knowledge and uncertainties surrounding a broader situation. The cognitive viewpoint emphasizes the individual's agency in formulating and satisfying their information needs (see Cole, 2012; Ingwersen and Järvelin, 2005). In Taylor's (1968) model, for instance, information needs are experienced as an evolving cognitive process that transitions from unconscious and unexpressed to conscious and expressed needs. The individual defines and redefines their information need as their understanding develops. Building on Taylor's work, Cole (2011) posits that while the individual's perception of their information need may change during task performance, the underlying reality of the information need remains constant. In other words, the cognitivist viewpoint suggests that the information need stays the same throughout the individual's process of negotiating it. This conceptualization of information needs as fixed aligns with the prevalent metaphor of an information need being a gap to be filled or bridged, as proposed in Dervin's (1992) sense-making model.

The socio-cultural perspective offers an alternative to the cognitive viewpoint in understanding information needs. It situates individuals within a broader socio-cultural context, emphasizing the fluidity of information needs, contrasting with the fixed nature proposed by the cognitive viewpoint. Byström and Kumpulainen (2020) explain that recurring situations, characteristic of many work tasks, can produce similar information needs in task-based understandings. They argue that these needs may arise from the socio-cultural context in which individuals participate, rather than solely from the individual. Consequently, information needs are conceptualized as fluid, resulting from activity and shared understandings of appropriate responses to situations and information needs (Byström, 2007). Savolainen (2012) introduced a contextualist approach to understanding information needs, identifying three major contexts: the circumstances from which a need for information arises ("situation of action"), the process of executing a task that requires information ("task performance"), and the conversational exchange between two or more individuals ("dialogue"). These contexts are not separate but intertwined, influencing the formation and satisfaction of information needs. When examining the concept of information needs from the socio-cultural perspective, it is crucial to consider the contexts in which these needs arise. This understanding provides insight into how socio-cultural factors influence information needs and behaviors.

Taylor's (1991) approach to studying information use revolved around understanding how people determine what information is useful to them in specific contexts, which he terms *information use environments*. These environments include a number of factors that impact information selection and use. Taylor proposed a structured framework for analyzing information use, which encompasses people, problems, settings, and solutions. Taylor focused on groups of people rather than individuals, specifically looking at divisions among professions (e.g. engineers, lawyers, physicians, scientists, social workers, or teachers). He argued that each group faces unique problems arising from their particular settings and the demands of their work. The setting within these information use environments pertains to the conditions and attributes in which people and information interact. These conditions are influenced by factors such as organizational structures, domains of interest, information accessibility, and the history and experience within an organization. Taylor's interest extended to how problems within these groups are resolved. He examined the types of information required by specific groups and how they use information. Taylor identified different categories of information use and characteristics of the information employed to address various problems.

This section reviewed the theoretical aspects of information needs within library and information science, and Taylor's structured framework for studying information use in context. Building upon this, the focus now shifts to how these concepts manifest in the information-seeking behaviors of undergraduate students. By examining the literature on undergraduates' information-seeking behaviors, I have identified factors that shape their use of information, including disciplinary context and the impact of convenience and familiarity.

2.2 Undergraduate information-seeking behaviors

The existing body of research has identified a number of dimensions related to the information-seeking behavior of undergraduates. I examine the impact of convenience, help-seeking patterns, disciplinary contexts, and the evolution of strategies employed by undergraduates.

The literature consistently highlights undergraduates' preference for familiar and easily accessible sources. Connaway *et al.* (2011), Komissarov and Murray (2016), and Lee *et al.* (2012) document this inclination. The path of least resistance is emphasized by Lee (2008), Twait (2005), Valentine (1993), and Warwick *et al.* (2009). A contemporary shift to online sources is evident (Komissarov and Murray, 2016; Lee *et al.*, 2012), influenced by time constraints discouraging exploration of new information-seeking modes (Lee, 2008; Twait, 2005).

Undergraduates commonly seek help from peers, family, and instructors, often bypassing librarians, as indicated by Beisler and Medaille (2016), O'Brien and Symons (2005), Pellegrino (2012), and Thomas *et al.* (2017). However, Pellegrino (2012) notes that targeted interventions, such as library instruction sessions, can positively influence students to seek librarian guidance.

Disciplinary differences shape information-seeking approaches. Variances between STEM and humanities students, as indicated by O'Brien and Symons (2005) and Whitmire (2002), highlight differences in information-seeking behaviors. Biglan developed a model of disciplinary differences (1973a, b). Then, Whitmire (2002) applied this model to the information-seeking behaviors of undergraduates. Whitmire found that *soft, pure, life disciplines* (as defined by Biglan, e.g. anthropology, political science, psychology, and sociology) necessitate more extensive information-seeking efforts compared to *hard, applied, non-life disciplines* (e.g. computer engineering, computer science, electrical engineering, and mechanical engineering). Humanities and social science students tend to physically browse library shelves (O'Brien and Symons, 2005).

Research reveals a disparity between information-seeking behaviors of undergraduates and emerging professional. Bodi (2002), Drabenstott (2003), and Heinström (2005) demonstrate that undergraduates generally use less sophisticated strategies, whereas upper-year undergraduates and graduate students exhibit more advanced behaviors (Callinan, 2005; Twait, 2005; Warwick *et al.*, 2009). The literature underscores the multifaceted nature of undergraduate information-seeking behavior, encompassing considerations of convenience, help-seeking patterns, disciplinary contexts, and the evolving sophistication of strategies employed. These insights form a foundation for understanding how undergraduates navigate their disciplinary information use environments.

The information-seeking behaviors of undergraduate engineers align with these general trends. Undergraduate engineers tend to satisfice by choosing information that is familiar and at hand (Denick *et al.*, 2010; Fosmire, 2014; Kerins *et al.*, 2004; Mercer *et al.*, 2019; Waters *et al.*, 2012; Wertz *et al.*, 2011). Additionally, they seek help from peers and consult personal collections of materials before resorting to search databases (Dodson *et al.*, 2019; Kerins *et al.*, 2004; Leckie and Fullerton, 1999). The level of education also influences how undergraduate engineers interact with information, as students in upper-years integrate more academic sources into their written work than students in lower-years (Atman *et al.*, 1999, 2005; Yu *et al.*, 2006).

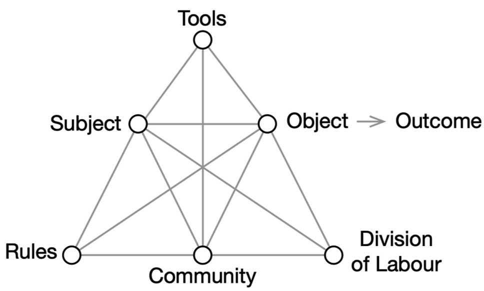
The exploration of undergraduate information-seeking behavior, as discussed in this section, provides a foundation for understanding the complexities of how students engage with information in their academic pursuits. However, to gain a deeper understanding, I employed a theoretical framework that considers the social and cultural contexts in which information seeking takes place.

3. Theoretical framework

Activity theory is a framework for understanding activities in context by describing the relationships between individuals, their goals, tools, and communities. Nardi (1996) highlights the usefulness of activity theory's conceptual vocabulary in describing the context, situation, and practice that both shape and are shaped by the activities individuals and groups engage in. Scholars have argued that activity theory provides a theoretical lens to describe information behaviors (Allen *et al.*, 2011; Wilson, 2006), and offers an "overarching paradigm" for connecting areas of research across library and information studies (Wilson, 2008).

An activity system is comprised of several interconnected elements (see Figure 1). The *subject* is the individual engaged in the activity, whose point of view is the focus. *Tools* are the physical or symbolic objects that participants use to engage in the activity. The *motive* is the purpose for the activity, including an object and an outcome. The *object* is the short-term goal(s), whereas the *outcome* is the long-term goal(s). *Community* is the group of individuals who shape the activity. Individuals follow *rules* while engaging in the activity (e.g. agreements, conventions, and laws). *Division of labor* is how the work of the activity is divided among participants. Learning is an active, constructive process within activity theory, characterized by interdependencies between people, information, and tools, and influenced by the spaces in which it takes place (Engeström, 2015).

Activity theory focuses on subjects who interact with activity systems to achieve their motives (Kaptelinin and Nardi, 2006; Nardi, 1996). Subjects' interactions are *mediated* by tools for subject–object interactions, rules for subject–community interactions, and division of labor for community–object interactions (Engeström, 2015). Additionally, knowledge can be *externalized* in the activity system, or *internalized* in the subject. All elements of an activity system can *develop* over time (Engeström, 2015). Activity theory adopts a cultural-historical perspective, emphasizing the resolution of *tensions* within or between activity systems as a driver of change. Engeström (2001) notes that contradictions represent accumulated tensions between elements of an activity system. Resolving these tensions leads to the changes in the activity system. The aim of activity theory is to better understand how elements interact and shape activity over time.



Source(s): Figure by author

Figure 1.
An activity system

Activity theory offers a lens through which to examine the relationships between individuals and their tools, communities, and goals, emphasizing the interplay between the subject's information behavior and their broader sociocultural context. Activity theory provides a consistent vocabulary for understanding and articulating how individuals are positioned within their activities, tools, and communities as they pursue their goals. It presents a context-sensitive view of information interaction and has been used to examine learners' behaviors (e.g. Bazerman, 2004; Russell, 1997). By drawing on activity theory in the study's data collection and analysis, I focus on the situated nature of information seeking and the various factors that shape the behaviors and experiences of undergraduate engineers in their academic setting.

4. Methods

This paper reports on a qualitative case study of undergraduate engineers, which is part of a larger, mixed methods research project (Dodson, 2021, 2022, 2023; Dodson *et al.*, 2024). I recruited undergraduates from multiple engineering programs, and conducted semi-structured interviews. I used the activity theory checklist (Kaptelinin *et al.*, 1999) to gain insights into the context of undergraduate engineering education related to the research questions. The interviews were recorded, transcribed, and then interpreted with thematic analysis. The analysis involved generating codes, identifying themes, and exploring relationships between themes.

4.1 Setting and participants

I recruited 18 undergraduates enrolled in bachelor's programs in computer engineering (CE), electrical engineering (EE), and mechanical engineering (ME) at a large Canadian research university. I selected students in second, third, or fourth year standing, because I expected that these students would have sufficient experience with engineering education. I recruited participants from a previous study that indicated that they would be interested in participating in future studies. I contacted these participants individually via e-mail with a recruitment poster, inviting them to interview. Data saturation was reached after 14 interviews; however, I conducted an additional four interviews for a total of 18 interviews (see Table 1).

4.2 Interviews

I explored students' information needs and use through semi-structured interviews. Interview questions were informed by activity theory. I used the activity theory checklist, which is a tool for incorporating questions about aspects of the activity system to better understand the participants' context and situation. Questions inquired into interviewees' program and year of study, academic activities, use of information and technology, and the development of their identities as emerging engineers. I interviewed participants individually in a lab-based environment for approximately 45 min. The semi-structured nature of the interviews allowed me to adjust the order of questions and ask follow-up questions to clarify

Program	Year			Total
	2nd	3rd	4th	
CE	0	1	2	3
EE	0	3	2	5
ME	1	3	6	10
Total	1	7	10	18

Table 1. The participants, aggregated by program and year of study

their answers or follow up on unexpected threads of conversation. The audio of the interviews was recorded. A total of 14 h of interviews were recorded from the 18 interviewees, with an average interview length of 46 min ($SD = 2.45$ min). I transcribed all spoken content, including the questions and responses.

4.3 Data analysis

I analyzed the transcripts with thematic analysis, following the guidance of Braun and Clarke. Braun and Clarke (2006) identify six phases of thematic analysis: familiarizing yourself with the data, generating initial codes, searching for themes, reviewing themes, defining and naming themes, and producing the report. This type of thematic analysis is flexible enough to be implemented with different theoretical frameworks. The researcher moves between the data and the developing codes and themes.

I identified important parts of the transcripts and coded them with a label. Both inductive and deductive codes were used to analyze interview transcripts. Deductive codes were drawn from activity theoretical concepts and the previous literature. Inductive codes were created while analyzing the interview data. I noted recurring attitudes and activities across multiple interviewees. The inductive codes related to students' learning environments, including their official and unofficial sources of information with respect to information seeking, use, and creation. After the initial coding, I grouped codes into potential themes. I combined themes into a larger narrative using, in part, thematic networks (Attride-Stirling, 2001) to visually explore, describe, and summarize the relationships between themes.

5. Results

I generated two themes: the first theme focuses on the specific difficulties undergraduate engineers face during problem solving tasks, highlighting the importance of procedural knowledge and the value students placed on understanding the problem solving process. The second theme explores the significant role of peers as sources of information, including the use of step-by-step solutions and program-specific repositories, and the prominent use of Facebook Messenger as a platform for information sharing and collaborative problem solving among students.

5.1 Theme 1: undergraduate engineers' challenges with problem solving

The first theme investigates the specific difficulties students encounter during problem solving tasks, emphasizing the frequency of procedural hurdles rather than conceptual ones. In the first subtheme, I explore how students seek out step-by-step solutions to overcome these obstacles and the value they place on understanding the process behind solving a problem rather than simply obtaining the correct answer. In the second subtheme, I examine the role of practice in honing students' problem solving skills, particularly in the context of complex exam questions.

5.1.1 Procedural information needs: "this one small thing that I keep missing". The interviewees reported difficulties with the types of problem solving tasks that comprise homework assignments, labs, tutorials, and exams. They expressed the need for a specific type of information to overcome these challenges: step-by-step solutions. Interviewees said that step-by-step solutions are more useful than answers, as they guide students through the problem solving process. Additionally, the interviewees emphasized the significance of practice in internalizing the know-how required for efficient and accurate problem solving.

All interviewees shared their experiences of encountering obstacles while engaging in problem solving tasks. These challenges are typically related steps for calculating a value, rather than a lack of conceptual understanding or knowledge of the appropriate equations to apply. In these situations, the interviewees said that they usually have an understanding of the underlying concept. Instead, they are stuck because of a wrong step in their calculation which stops all progress towards solving the immediate problem. I refer to this as a *procedural hurdle*.

Arun (3rd year ME) said he more often becomes stuck due to steps in the problem solving process rather than conceptual gaps or misunderstandings:

> Usually, I have a pretty good grasp of the concept, unless it is really early on in the course or really late and I just haven't been doing stuff. But, yeah, it is probably like this one small thing that I keep missing. I look at some person [on the Web] who answered a similar question – or even the same question, if I am are really lucky. I look at their steps and I try to follow along, because usually I have done most of the question. Then I am like, "Oh, I forgot that this force cancels that," or something. It is usually a small thing.

To address their information needs, interviewees reported seeking out step-by-step solutions. Interviewees made a distinction between answers and step-by-step solutions. For example, Zhiming (4th year ME) said:

> I find it most helpful when not only the problems [and answers] are available, but clearly described solutions. So, not just this is the problem and this numerical value is the answer, but this is the problem and this process is how you get to the answer. . . . It is not going to help me if I just know the number I am supposed to get in the end. It is going to help me if I am able to work through the solution and understand what is happening to get me to the answer.

Interviewees said that most instructors do not provide solutions. Arun (3rd year ME) said:

> Sometimes [instructors] don't [provide step-by-step solutions], and it is like, "Yeah, I can do [the problems], but what if I am doing them wrong?" There is no way to correct myself. There is no way to improve. Please have steps or at least something explaining how you got that final answer. Having just the right answer is almost as worthless as not having an answer, even though I can be like, "Yay, I got it right." But if I don't, then I am still stuck, right?

Interviewees said proceeding step by step through solutions helps them better understand why they became stuck on the problem. For example, Hossein (4th year ME) said:

> When I see how they describe the process, I kind of understand it a little bit. Then I can do it myself and complete the problem.

In the first subtheme, I considered interviewees' experiences of becoming stuck on problem solving tasks. I refer to these as procedural hurdles. I also highlighted the importance of step-by-step solutions in overcoming these barriers, and emphasized the distinction between answers and solutions. The interviewees expressed the benefits of reviewing such solutions to enhance their understanding and problem solving skills, and expressed a desire for instructors to provide more support in the form of providing step-by-step solutions. Interviewees reported using step-by-step solutions for practice, which is discussed in more detail in the following subsection.

5.1.2 Practice solving problems: "the how-to-do-it from a lot of practice problems". In the second subtheme, I investigate the role of practice. Most interviewees shared that practice is vital in tackling more difficult problems, especially those on exams. They said that they become faster and more accurate problem solvers by practicing. For example, Jing (3rd year ME) said:

> Definitely working through [practice problems is important]. Yeah, because that was my mistake in [second year]. I would look at the problems and be like, "I know how to do that. We did that in lecture. I understand it. Great. Move on." Then I would get a question similar to that in an exam, and I would just freeze and I would be like, "Whoa?!". Yeah, definitely having the conceptual stuff from the lectures, but also the how-to-do-it from a lot of practice problems.

As noted in the previous subtheme, interviewees said that procedural hurdles often cause them to become stuck on their task. They shared that they use step-by-step solutions as a type of practice – i.e. by checking when, why, and how they became stuck in the problem solving process. However, interviewees said that their instructors rarely provide them with answers or solutions. Consequently, interviewees said they had to seek out this information on the Web or ask their peers for help.

When asked whether they can use Piazza, the discussion forum, to ask for help, interviewees explained that their instructors prohibit them from sharing answers. For example, Benjamin (3rd year CE) said:

> There are things that you wouldn't discuss on Piazza with the entire class, like "Can we compare homework answers?" You wouldn't just post your solutions on Piazza and be like, "Can everybody check my work?", because that would be against the rules. We do that in a more private setting, where the instructors aren't seeing it.

In the second theme, I investigate the "private settings" that students use for sharing step-by-step solutions.

5.1.3 Summary. In the first theme, I explored the experiences and strategies of students when it comes to problem solving. Interviewees frequently indicated that their information needs stem from problem solving tasks. The specific information required varies by program – for instance, an EE student might focus on problems involving electromagnetism or signal processing, whereas a ME student might work on problems involving heat transfer or vibrations. However, similarities across programs are clear. A frequent challenge for all interviewees is understanding the next step in an ongoing problem. They explained that they often seek assistance when they are unable to understand the next step in an ongoing problem. Interviewees noted the importance of step-by-step solutions in overcoming these hurdles. They shared that step-by-step solutions allow them to work through their problem solving tasks and gain a better understanding. However, most instructors do not provide such solutions for homework or practice exams, leaving students uncertain about their progress and unable to self-correct. Interviewees emphasized that practice problems contribute to increased speed and accuracy in problem solving, including solving more complex and challenging problems like those on exams. With these insights into the value of step-by-step solutions, I now examine the role of group chats in facilitating problem solving.

5.2 Theme 2: collaborative information sharing as peer instruction

The second theme examines the significance of classmates and friends as information sources. It highlights how students seek information from their peers, including step-by-step solutions and access to previous course materials. The first subtheme reveals the use of program-specific repositories, which work around instructors' attempts to withhold these materials. In the second subtheme, I describe the interviewees' prominent use of Facebook Messenger as a primary platform for information sharing between peers. This subtheme explores how group chats on Facebook Messenger serve as spaces for seeking help, sharing solutions, and engaging in discussions related to coursework. The second subtheme also investigates the rules and contextual factors that influence the effectiveness of group chats.

5.2.1 Course materials: "your friends in upper years share this [Google] Drive with you". All interviewees said that their peers are an important source of information, including step-by-step solutions and materials from previous courses. When seeking course materials, most interviewees described reaching out to other students who had already completed the course. Similarly, interviewees in their last year of study described providing materials to other students. For example, Liam (4th year ME) said:

> I obsessively download everything. I would bet money on the fact that there is not a single thing that has been posted on any of my course websites that I have not downloaded in the last four years. I keep a fairly well-organized file structure, so I often have people in lower years asking me about things, and I can go get them from two years ago because I have them filed away.

Interviewees described using online repositories of course materials. Hossein (4th year ME) described a repository:

> There is an online [Google] Drive that has information on all the [Mechanical Engineering] classes. All the classes from second year to fourth year. I don't know who runs it, but it has all the class notes and assignments from a certain year – I think 2014 or 2015. So, it's not updated to the latest year, but it does have all the information.

The repositories are shared and used secretively, because these platforms work around instructors' efforts to withhold access to course materials.

Christine (4th year ME) shared her experience with a repository:

> I think [the materials are] probably passed more between friend groups. So, your friends in upper years share this [Google] Drive with you. . . . I think it is probably one person's notes that they shared with their friends at their year, and then their friends shared with our year, and our year shared it amongst ourselves. But, the [Google] Drive is shared over [Facebook] Messenger. We have a group chat, and we are like, "Oh, yeah. Check this out." You know? . . . Lectures and homework and labs and practice exams – it is usually all the course material. It is probably going to match up to your course material as well. The only difference is that it might also have the answers.

In this subtheme, I explored the significance of peers as a valuable source of course materials. Interviews revealed that students obtain previous course materials from their peers, particularly those who have already completed the course. I observed the use of online repositories of course materials. Students use these in order to circumvent instructors' attempts to restrict access to information. In the next subtheme, I consider the role of Facebook Messenger as the primary platform for collaborative information sharing between peers. I explore the dynamics of group chats facilitated by Facebook Messenger, investigating how students leverage this platform for collaboration, particularly in the context of homework assignments.

5.2.2 Group chats: "the whole reason I have a Facebook account". All interviewees reported using Facebook Messenger for coursework. Facebook Messenger, rather than Piazza (the official discussion form), is the primary site of peer-based learning. Zhiming (4th year ME) said messaging classmates about assignments is "the whole reason I have a Facebook account." interviewees said that group chats are most helpful for asking for help from classmates. For example, Arun (3rd year ME) said:

> If I am stuck on a question, I will ask [my friends on Facebook Messenger]. If they have a better understanding, obviously, they will try and explain it and go through the question. Sometimes it is just like I missed a little step, and then it all clicks, so then it's fine. Sometimes it is like the general concept. They can try and explain it in their own words, which is on a student-level so it is kind of more relatable and it might be easier to understand, so that helps a lot too. Other than that, it is just debating what we learned in class. That gives you a better understanding, because you are arguing for what you think is right. If you are proven wrong, then good – you learned something.

Facebook Messenger was primarily used for help on homework problems. Interviewees explained that they would message their peers to ask for help. Emma (3rd year ME) said:

> If someone has a question, they would usually send the number of the question and maybe a picture of what their attempt at the problem was and how they went wrong. Then, someone would send back the solution to help them.

Christine (4th year ME) said:

> I think [Facebook Messenger] is most effective in circumstances where both people know what they are doing, but maybe you are confused about one step. Then, the other person sends a picture [of their work], and you compare your solutions and you are like, "Oh, yeah! This is the step where I went wrong."

5.2.2.1 From impersonal to personal. In exploring the dynamics of students' information seeking using group chats, I considered the development of these groups as sites for information sharing. In this subtheme, I investigate the emergence of large group chats encompassing a multitude of students within the same cohort, and their subsequent transformation into smaller, more cohesive circles of friends with shared academic interests. By comparing these different types of group chats, I gained insight into the students' preferences. Such transitions reflect the dynamic nature of collaborative learning environments, where the peer learning intertwines with social connections and information sharing.

Thomas (3rd year EE) described a large group chat:

> There is this [group chat on Facebook Messenger] – I don't know if it has every single person in [Electrical Engineering] in it, but it sure seems like it. There is something like a couple hundred people in that group chat. That one was more useful in [second year], when everyone was taking the same courses. For example, I would get stuck on a [homework] problem, so I would just go to that group chat and I would Control-F and I would see that, "Oh, some people had a conversation about it like two hours ago." So, I will just read through that, and usually there is useful information in there, because they are working on the exact same problem that I am. . . . I mean [the group chat] can be useful, because of the number of people that are made accessible through it. But, because it is an unfiltered source of information, there is a lot of other talk on it. There are a lot of memes and just irrelevant stuff. I mean, it is entertaining, but it is not the information I am looking for. So, nowadays it is muted, and I don't check it nearly as often.

Most interviewees said that they have moved from larger group chats to smaller ones, comprised of classmates who are friends. Jing (3rd year ME) said:

> The whole 100 people group chats definitely don't work, at least for me. I like it when I actually know everyone in the group before I post something.

Zahra (3rd year EE) said:

> I think a lot of [my preference for smaller group chats] is virtual anxiety. It's always hard to message a group of 200 people and be like, "Hey, I am struggling." That part of it is much easier [with smaller group chats]. You can reach out to your friends much faster, right?

I asked Jing (3rd year ME) how she and her friends began to use a group chat. She said:

> These [Facebook Messenger] group chats just tend to start in social circles, I would say. Then, because we are taking a lot of the same courses, it ended up being like, "Hey, does anybody know the answer to this?", or "Did anyone get this question?" Then, you just have people helping.

5.2.2.2 Norms and expectations. In the previous subtheme, I described the group chats and interviewees' preferences for participating in small rather than large groups. I now consider the rules of the group chats. Understanding the rules of students' group chats – as defined by activity theory – is crucial to understanding how peer interactions on Facebook Messenger are mediated through norms and expectations. In smaller groups chats, participants reported being more willing to spend time and effort helping classmates. Similarly, they had greater expectations for receiving help. Zahra (3rd year EE) compared her experiences in both large and small groups:

> I think there is always an element of [knowing] how much asking is too much asking. That boundary is a little bit looser with friends, whereas other classmates might get offended, like "Why are you not solving this on your own? Just spend eight hours and figure it out yourself."

Jing (3rd year ME) talked about sharing information amongst undergraduate engineers:

> Everyone is pretty willing to help [on group chats]. I have never really felt like, "Oh, I don't want to help you, because what if I don't ride the curve anymore?" Yeah, there is not really any of that in any engineering – even outside my own personal friend group chats.

The implicit rules appear to recognize that classmates have limited time, and that they have no obligations to help. Alaa (4th year ME), shared a recent experience helping a classmate on Facebook Messenger:

> Yesterday, my friend was kind of confused about one of the questions, and I said, "I am sorry, I don't really have time to explain it." So, I just sent her [a picture of] my assignment, so she could see my steps and check if she got the same answers.

Rules and the division of labor can change in response to several contextual factors. For example, Arun (3rd year ME) described how his workload can determine whether he would answer a peer's question:

> It depends on what time of year it is. If it is early on, I will probably help them through the steps. But, if it is right before midterm season, I think I will just take a picture [of my solution] and close the chat, so I don't have to answer any questions. But then other people might jump in and just give them a line or two, like "This, this, this", or like "You did that wrong", or something like that.

Similarly, Jing (3rd year ME) said the type of question being asked can affect responses:

> It really depends on the problem that the person asked in the chat. There are a lot of photos of answers, because a step-by-step solution is really helpful when learning how to do things. So, a lot of the time it is much easier to just take a picture and then explain it or try and go through it.

Expectations have a significant influence on how students' use group chats. Interviewees prefer smaller, close-knit group chats. The rules in these group chats recognize that peers have limited time and no obligation to help, but there is still a willingness to help their classmates. Contextual factors, such as workload and the type of question being asked, can impact the extent of support provided. The interviewees expressed a preference for Facebook Messenger over "official" platforms like Piazza due to the more private and unrestricted nature of sharing solutions.

5.2.3 Summary. The second theme highlighted the role of peers and platforms in supporting collaborative learning. In the first subtheme, I described peers as sources of information, with students sharing course materials through Google Drive. In the second subtheme, I emphasized the central role of Facebook Messenger in facilitating problem solving through group chats. This subtheme also included a description of how these group chats develop, revealing a shift in interviewees' participation in larger group chats to smaller ones. The rules of the group chats support information sharing, while also recognizing that members' ability to provide assistance is impacted contextual factors, such as workload.

The first and second themes are connected, as information needs, seeking, and sharing are related activities. This examination of undergraduate engineers' behavior highlighted the evolving dynamics, norms, and support networks that enhance knowledge exchange and foster academic success.

6. Discussion

This section brings the empirical findings and the existing research literature together, addressing the research questions that guided this study. I incorporated activity theory in the analysis and interpretation of the findings, as demonstrated by applying its terminology (see Theoretical Framework).

6.1 Conceptual and procedural information needs

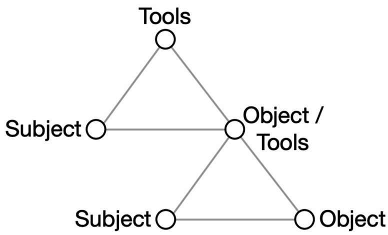
Undergraduate engineering students often encounter task-based information needs, which can be classified as gaps in either conceptual or procedural knowledge (RQ1). Recognizing whether the information need is rooted in conceptual (know-what) or procedural (know-how) knowledge provides insight into students' learning process and their socialization into the field of engineering. Students' pursuit of procedural information signifies the evolution of their problem-solving skills and expertise.

STEM education scholars distinguish between two types of knowledge: *procedural knowledge*, often referred to as know-how, and *conceptual knowledge*, known as know-why (McCormick, 1997). Procedural knowledge encompasses the specific step-by-step processes or actions required to solve problems within a particular discipline (Rittle-Johnson and Siegler, 1998). In the context of engineering, the differentiation between conceptual and procedural knowledge holds particular significance, where procedural knowledge pertains to the established procedures, protocols, and routines (Barak, 2013). McCormick (1997) emphasizes that the design process and problem solving activities exemplify prime examples of procedural knowledge. Conversely, conceptual knowledge involves an understanding of the underlying concepts and interconnectedness of constructs (Kilpatrick *et al.*, 2002). A study by Crooks and Alibali (2014) that surveyed various definitions of conceptual knowledge reveals that it is commonly defined as the awareness of meaningful relationships within a given domain. This aligns with the work of Hiebert and Lefevre (1986), who characterizes conceptual knowledge as being rich in semantic relationships.

Undergraduate engineers frequently require procedural information, especially when engaged in problem-solving tasks found in homework, labs, tutorials, and exams. While students typically understand the underlying concepts, they face challenges in executing the specific steps necessary to solve problems. The distinction between conceptual and procedural knowledge is important, as conceptual knowledge involves understanding relationships, while procedural knowledge focuses on knowing the required actions. Nonetheless, this distinction is under-theorized in the information needs literature.

In his writings on the philosophy of science, Kuhn observed that physics students often believe that they understand the theories and concepts from their textbooks, but struggle solving problems at the end of chapters (1977). Kuhn emphasized that students do not typically overcome these issues by thinking more about the relevant laws or theories; instead, they do so by working through problems, which he referred to as *exemplars*. Exemplars refer to concrete problem solving solutions students accumulate throughout their education, be it in lectures, textbook exercises, or exams (1962). Kuhn argued that by developing a repertoire of exemplars, students develop the ability to identify how a new problem is a variant of one they have already encountered (1977). Consequently, problem solving is a fundamental activity in students' transition from newcomers to emerging scientists.

Students develop their procedural knowledge by completing many practice problems. Homework, for example, provides students with an opportunity to familiarize themselves with different types of problems and, importantly, their solutions. The interviewees suggest information needs frequently arise from uncertainty about how to solve problems. By working through many step-by-step solutions, students begin to internalize this know-how (see Figure 2). The more problems and solutions students internalize, the greater the variety of tools in their toolbox, what Kuhn refers to as students' repertoire. The degree to which students internalize procedural knowledge is a determinant of their future problem-solving success. For instance, interviewees discussed the importance of resolving their need for procedural information when working on homework to successfully apply this know-how in exams.



Note(s): Students use their prior knowledge and experience as tools to address the problem at hand (the object). Kuhn (1962, 1977) characterizes a student's know-how as a repertoire, developed through engagement in problem solving. While the students' immediate objective may be solving the problem and completing their homework, the activity also shapes the students' repertoire. This is evident in how the outcome of the activity system on top of this figure influences the tools available in the subsequent system on the bottom. This chain of activity systems, potentially extending to three or more, reflects the evolution of students' problem-solving abilities throughout their academic journey and beyond
Source(s): Figure by author

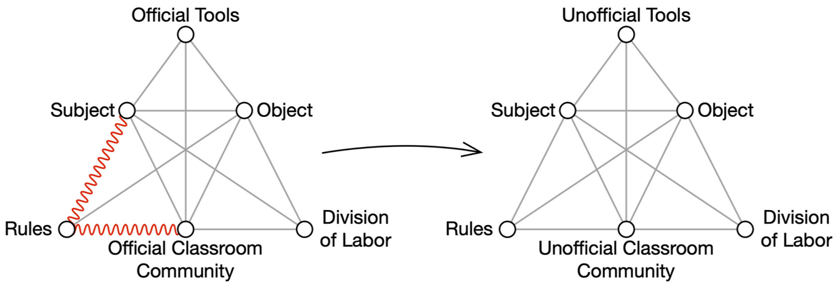
Figure 2.
In the activity system, students (the subjects) engage in problem-solving exercises (the activity)

6.2 Information sharing & backchannels

The findings indicate that undergraduate engineers often seek step-by-step solutions when they encounter procedural information needs (RQ2). However, instructors seldom provide this information, often misattributing students' need for information to gaps in conceptual rather than procedural knowledge. Instructors tend to withhold answers and step-by-step solutions, and they prohibit the sharing of such information in discussion forums. This creates a tension between students' information needs and instructors' control, particularly between the subject-rules-community components of the activity system. To work around this, students create and participate in student-only activity systems, which exclude instructors from the community and consequently have more permissible rules mediating the interaction between the subject (i.e. a student) and community (i.e. classmates) (see Figure 3).

When student cannot satisfy their information needs through the official activity systems, they search for information independently or seek peer support through various backchannels (RQ3). In this study, I identified two general types of student-only activity systems: (1) repositories of past course materials, hosted on platforms like Dropbox and Google Drive; and (2) group chats, primarily on Facebook Messenger.

The research literature has also identified the importance of peers in sharing information (Budny *et al.*, 2010; George *et al.*, 2006; Ramaswamy *et al.*, 2001; Stump *et al.*, 2011;



Note(s): These tools are governed by rules established by the instructor. Students' information needs often conflict with the instructor's norms for engagement, which typically prohibit sharing step-by-step answers and other course materials through official tools. This tension, represented by the red squiggly line between the subject-rules-community components of the official activity system, leads students to participate in an unofficial activity system, on the right of the figure, that excludes instructors. The unofficial system employs backchannels, such as Google Drive and Facebook Messenger, as tools. While rules exist in the unofficial activity system, there is more leniency for asking questions, answering them, and sharing course materials. These two activity systems coexist, with students selectively participating in either, depending on their needs
Source(s): Figure by author

Figure 3.
In the official activity system, on the left of this figure, students (the subjects) interact with the instructor's tools, such as the Piazza discussion forum

Watkins and Mazur, 2013). I built on this work by describing why and how students frequently collaborate through online *backchannels*, including file-sharing and instant messaging platforms. I found that backchannels support information sharing and learning outside the official platforms moderated by instructors. For example, students share previous course materials using Google Drive, and step-by-step solutions on Facebook Messenger group chats.

The use of backchannels may raise concerns about cheating, interviewees explained that they use these tools in order to improve their problem solving skills, not to cheat. By reviewing solutions, students are internalizing procedural know-how rather than engaging in academically dishonest practices. While it is possible that the interviewees were concealing their true motivations, it would seem unlikely. Using backchannels for cheating on homework assignments rather than learning is not likely an effective strategy in the long term. If students were using backchannels to cheat on their homework assignments, they would be unable to do the more difficult problems that appear on their exams. Exams are challenging, time-constrained, and comprise a significant portion of students' grades. By using group chats to just copy answers to homework assignments, students would not internalize the know-how required to solve problems. The resulting lack of proficiency would result in poor exam performances, and would likely mean that these students would be at risk of failing their courses.

The interviewees' preference for smaller Facebook Messenger groups over larger ones stems from factors such as familiarity, topicality, and usefulness. Students also feel more comfortable seeking help and participating in discussions within smaller groups. However, it is also important to critically examine the limitations of learning environments that are so heavily reliant on peer-based learning. The accuracy and comprehensiveness of information shared in group chats depend on the knowledge and understanding of the participants, which may result in incorrect or incomplete solutions. The absence of instructors in Facebook

Messenger group chats results in a lack of expert guidance, clarifications, and feedback that could better support students' learning and problem solving processes. Instructor involvement becomes crucial for addressing misconceptions, providing additional explanations, or correcting problem solving approaches.

Reflecting other studies of undergraduate students' information-seeking behaviors (e.g. Beisler and Medaille, 2016; O'Brien and Symons, 2005; Pellegrino, 2012; Thomas *et al.*, 2017), I found that the undergraduate engineers did not engage with librarians to seek help resolving their information needs. This may indicate an opportunity for further developing relationships between the engineering programs and liaison librarians, who might be able to provide useful services. One challenge here is that students are seeking information that may be difficult for librarians to assess without the domain-specific conceptual and procedural knowledge required to think like an engineer.

6.3 Summary

I identified the procedural and conceptual information needs among undergraduate engineers (RQ1). To address these needs, students draw from a number of channels and sources of information (RQ2). Notably, classmates supply each other with various forms of course-related information, including access to prior course materials and assistance through step-by-step solutions (RQ3). The findings underscore the dynamic nature of information-seeking behaviors among undergraduate engineers, emphasizing the important role of peers in the information use environment of undergraduate engineering education.

7. Conclusion

In this paper, I focused on the distinction between conceptual and procedural information needs, and the important role of peers in undergraduate engineers' information-seeking process. The findings revealed that students often face challenges with procedural information needs rather than conceptual gaps or misunderstandings when engaged in problem solving. Recognizing the distinction between know-what and know-how is vital for understanding these students' information needs. The study also identified tensions within students' learning environments, such as their limited access to course materials, restrictions to their interactions on official platforms, and instructors' reluctance to share step-by-step solutions. In response to these tensions, students develop their own alternatives, including repositories of course materials on Google Drive and group chats on Facebook Messenger. Addressing these tensions is crucial for educators looking to foster more supportive learning environments. Additionally, the study highlighted the importance of collaborative learning and peer interaction. Students consider their classmates as valuable sources of information, and seek help on assignments using platforms like Facebook Messenger. Peer interactions contribute to problem solving skills and the internalization of procedural knowledge. Educators could support collaborative learning by implementing more lenient rules that facilitate peer-to-peer interactions on the official platforms.

The university where the research was conducted shares many characteristics with other large research universities in North America, and it is likely that the sample is representative of undergraduate engineers at other universities.[1] Consequently, there is likely a sufficient degree of *fittingness* (Lincoln and Guba, 1985) and *proximal similarity* (Campbell, 1986) to suggest that the findings are transferable to engineering programs beyond the research site. The findings of this study are situated in undergraduate engineering education, but some of the findings, like procedural information needs and backchannels, might apply to other STEM programs.

I relied upon learners' self-reported use of information. This approach is common. Future work could triangulate the findings using other methods, such as observation. In the future, I may explore how students use backchannels over a semester or their entire program of study. I would also like to explore what instructors think about these backchannels. It may be beneficial to work with educators to figure out what procedural information students really need and how to support students through official platforms. By collaborating with instructors and students, I may be able to identify ways of destigmatizing or allowing the use of step-by-step solutions, while maintaining academic integrity.

In summary, I looked at how undergraduate engineers seek and share information. I found that these students often struggle with procedural information needs, meaning they understand the concepts involved but need help with the step-by-step procedures. Instructors do not always provide solutions, so students turn to their peers for help. Students use online tools such as Google Drive and Facebook Messenger to share course materials and solutions. This study highlights the importance of recognizing the difference between knowing what to do (conceptual know-what) and knowing how to do it (procedural know-how) in undergraduate engineering education. It shows that students value their classmates as sources of information and collaborate in order to improve their problem solving skills. Students' interactions through backchannels form an information use environment that helps them practice procedural knowledge. Backchannels hold opportunities and pitfalls for students and instructors when learners are developing conceptual and procedural knowledge in higher education STEM settings. Through these findings, I build on understandings of the experiential and sociotechnical elements of information needs to better reflect contemporary learning processes and activities in undergraduate STEM education.

Note

1. The Washington Accord considers undergraduate and postgraduate engineering programs in Australia, Canada, China, Costa Rica, Hong Kong, India, Indonesia, Ireland, Japan, Malaysia, Mexico, New Zealand, Pakistan, Peru, Russia, Singapore, South Africa, South Korea, Sri Lanka, Taiwan, Turkey, the United Kingdom and the USA to be functionally equivalent.

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