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Essential competencies for computing managers: Skills and dispositions

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Abstract

Competencies (knowledge, skills, and dispositions) enable employers and educators to speak a common language regarding what computing graduates are expected to demonstrate on the job. This study focuses on competencies required by managers in the computing industry, based on semi-structured interviews of ten individuals in managerial roles, such as directors, project managers, and product managers with prior experience in computing-related roles. Constant Comparative for Naturalistic Inquiry was used to analyze the data. The most frequently discussed managerial skills included leadership, project management, hiring and evaluating candidates, and mentorship. In addition, professional skills such as communication, problem-solving, and lifelong learning were mentioned, along with essential dispositions that support the development of these skills, e.g., collaborative mindset, lifelong learning orientation, and self-regulation. Participants also emphasized the need to make judgments, build relationships, and collaborate within or outside their team. Career readiness in the computing industry is not limited to entry-level jobs; professionals should have the opportunity to navigate their preferred career path—whether they aspire to move down a technical or managerial path. This study can contribute to both students' and educators' understanding of the managerial career path and what types of competencies and experiences should be included in computing education programs to set them up for success across their career path. Implications for pedagogical approaches will also be discussed.

Keywords Competencies · Dispositions · Managerial skills · Professional skills

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1 Introduction

This paper explores the competencies required by managers in the computing field. As defined in the Computing Curricula 2020 (CC2020), computing is an umbrella term that encompasses the professional fields of computer science, computer engineering, cybersecurity, information systems, information technology, software engineering, and data science (CC2020 Task Force, 2020). For this paper, we define computing managers as individuals in roles that require functional and behavioral skills for supervisory responsibilities in addition to relevant computing competencies (Indeed, 2021; Shet & Pereira, 2021).

Competencies are the knowledge, skills, and dispositions an individual needs to successfully perform goal-oriented tasks required in the workplace (CC2020 Task Force, 2020; Sabin et al., 2017; Woodruffe, 1993). To work and thrive in real-world work environments, professionals need not only domain-specific competencies but also skills that cut across different fields, such as communication, collaboration and teamwork, and lifelong learning skills (ABET, 2017; Caskurlu et al., 2017; Hart Research Associates, 2018). Dispositions, such as open-mindedness, empathy, kindness, humility, collaborative mindset, self-motivation, and the ability to work independently (Hart Research Associates, 2018; Shet & Pereira, 2021), positively impact computing professionals' actions and motivate them to follow through and perform a certain task (Frezza & Adams, 2020; Perkins et al., 1993; Sabin et al., 2018). Professional skills, such as communication, problem-solving, critical thinking, ethical reasoning, and teamwork, are also required across domains and job roles (Capretz & Ahmed, 2010; Hart Research Associates, 2018).

These skills and dispositions are not only essential in the initial stages of a computing career but are also beneficial across the career path that computing professionals traverse. For example, those in managerial roles in the computing industry, including project managers, Information Systems (IS)/Information Technologies (IT) managers, supervisors, and directors (Indeed, 2021), oversee the successful completion of projects and attainment of the team or company goals. Research has found that project managers require behavioral, socio-emotional, technical, managerial, leadership, and contextual competencies (do Vale et al., 2018; Kwiotkowska et al., 2021). In addition, managers need to demonstrate competencies in the context of their business function, which impact project performance, such as communication, planning, innovation, motivation, leadership, negotiation, etc. (Bashir et al., 2021; Lee et al., 2013; Moradi et al., 2020). Finally, as the computing industry becomes ever more pervasive across other industries, managers need to adapt quickly and demonstrate relevant competencies to steer their teams in a direction that yields preferred company-level outcomes, which requires new competencies to affect business and organizational impact (Dzwigol et al., 2020; Shet & Pereira, 2021).

As a reflection of the needs of computing employers, the focus and underlying foundation of computing curricular reports such as the *ACM/IEEE-CS Curriculum Guidelines for Baccalaureate Degree Programs in Information Technology 2017*

(CC, 2020 Task Force, 2020; Sabin et al., 2017) have been moving from knowledge areas and knowledge units to student performance and demonstration of competencies – knowledge, skills, and dispositions as required in the computing workplace. This is reflected in the ABET's, 2022–2023 accreditation criteria (ABET, 2022) and the IT2017 and CC2020 curricular guidelines (CC2020 Task Force, 2020; Sabin et al., 2017; Topi, 2017).

Hearing directly from those currently working in the field can help us understand how to prepare students for not just their first job but a career in computing. Based on semi-structured interviews of 10 managers who have previously served in technical roles, this exploratory qualitative study explores the managerial and professional skills and dispositions they require to succeed in their current roles. This is an extension of Duan et al. (2022c).

2 Literature Review

2.1 Competencies

Competency refers to the expertise individuals can demonstrate in their professional, educational, and/or life contexts (Sabin et al., 2017). In a professional context, an individual needs many competencies to successfully perform goal-oriented tasks required in the workplace (CC2020 Task Force, 2020; Woodruffe, 1993). The construct of competency, as introduced to the computing education world in the IT2017 curricular report (Sabin et al., 2017), comprises knowledge, skills, and dispositions. Knowledge involves the concepts, topics, and information specific to a domain based on scientific proofs and theories (Clear et al., 2020). Skills are the capabilities and strategies that enable an individual to perform tasks successfully using the relevant knowledge in a given context (Clear et al., 2020). These can be either domain-specific or domain-agnostic. Finally, dispositions are values, attitudes, and motivations that guide an individual to know when and why to perform a task using the skills and knowledge relevant to the context (Clear et al., 2020). As Sabin et al. (2018) described, knowledge, skills, and dispositions represent three dimensions of competency: ' know-what,' 'know-how,' and 'know-why/know-yourself', respectively. Students' career readiness in computing education programs is defined by honing their abilities along these three dimensions (CC2020 Task Force, 2020).

While the concept of skills and knowledge are familiar to most, studies that identify competencies required by managers generally do not differentiate between professional skills and dispositions (Lee et al., 2013; Shet & Pereira, 2021). When dispositions are discussed in the literature, they tend to be associated with personality types suitable for different roles (Capretz & Ahmed, 2010; Janz & Honken, 2013; Varona et al., 2012). However, dispositions are not merely static attributes of one's personality; they can be learned and developed (Frezza & Adams, 2020; Nieto Carracedo & Saiz, 2011). Furthermore, the distinction between professional

skills and dispositions is important, especially for educators, since the pedagogies used to teach professional skills and dispositions may differ (Katz, 1993), allowing management and computing programs to align curricula and foster appropriate competency development. Therefore, it is helpful to distinguish professional and managerial competencies that are dispositional, such as emotional intelligence (do Vale et al., 2018), collaborative mindset (Shet & Pereira, 2021), and flexibility (Janz & Honken, 2013).

2.2 Competencies required by computing managers

The U.S. Bureau of Labor Statistics (2022) lists the following "important qualities" required of IT managers: analytical, business, communication, decision-making, leadership, and organizational skills. In addition, managers play a critical role in the hiring process for recruiting computing professionals. Shet and Pereira (2021) proposed a competency model based on 14 managerial competencies identified in a systematic literature review (SLR) related to Industry 4.0: agility, entrepreneurial intelligence, connected technology architecture, business acumen, design thinking, problem-solving and decision-making, collaborative mindset, disruptive leadership, research orientation, sustainability, robotics process automation, digital intelligence modeling, data analytics, and project leadership. Do Vale et al. (2018) conducted an SLR and analyzed job postings in Brazilian organizations and found that the most frequently appearing competencies include what they termed behavioral competencies (leadership, communication, emotional intelligence), technical competencies (engineering and software domain knowledge and the ability to use specific software), and management competencies (planning, executing, monitoring, and controlling projects) and contextual competencies (understanding relationships, processes, project and the organizational environment).

This is also important for executive management, especially technical leaders such as chief information officers (CIOs). Janz and Honken (2013)'s recommendations for being CIOs in IT organizations include: coordinating the work of others, solving problems, making equipment purchases, scheduling installations, thinking strategically about the development and implementation of an IT plan, visioning the future, and reorienting the basic approach to the conduct of work in the area. A CIO also must assess organizational needs and personal relationships with the institution and be flexible to adapt to environmental circumstances. Managerial competencies also include understanding "situational politics," the politics of the organization and the work environment (Ho & Frampton, 2010; Jones et al., 2018), and organizational readiness or opportunity skills (Gallagher et al., 2010).

Managers (listed as "directors" by the Bureau of Labor Statistics) are often directly involved in hiring members of the IT department, according to the U.S. Bureau of Labor Statistics (U.S. Bureau of Labor Statistics, 2022). Although "personal traits" and fit within a company are often not explicitly included in job advertisements, managers need to be able to assess them when hiring technical staff (Armstrong et al., 2020; Chinn & VanDeGrift, 2008).

2.3 Managerial Competencies in Computing Undergraduate Degrees

Managerial competencies are developed in professional graduate programs, such as MS Information Systems (MS IS) or Master in Business Administration (MBA). However, undergraduate degrees may lay a foundation for these competencies, many of which are also important in non-managerial roles. Curricular guidelines for undergraduate programs are frequently revised to keep up with evolving changes in the field (Berkling et al., 2019; Hollister et al., 2017; Li et al., 2021; Schirf & Serapiglia, 2017). For example, starting in the IT2008 curricular report (Lunt et al., 2008), the knowledge area of "Social and Professional Issues" was added to include professional practice and the social context of computing. The IT2017 competency-based curricular framework introduced the essential competency domain "Global Professional Practice," including project management principles, communication, teamwork and conflict management, employability skills and careers in IT, professional skills and responsibilities, etc. (Sabin et al., 2017). A supplemental competency domain, "Social Responsibility," addressed goals, plans, tasks, deadlines, and risk management. Similarly, ABET's, 2022–2023 accreditation criteria (ABET, 2022) include the IT-specific student outcome "use systemic approaches to select, develop, apply, integrate, and administer secure computing technologies to accomplish user goals."

The need to align with industry requirements in the emerging markets (Nankivell et al., 2010) is impacting how we think about computing education in general, and preparation for managers in this area in particular. Other frameworks that list the required competencies for professionals working in computing fields include Software Engineering Body of Knowledge (SWEBOK); Software Engineering Body of Skills (SWEBOS); Skills Framework for the Information Age (SFIA); and National Initiative for Cybersecurity Education (NICE) (Bourque & Fairley, 2014; Newhouse et al., 2017; Sedelmaier & Landes, 2015; SFIA Foundation, 2021). While not all of the competencies identified in these frameworks are required at the new-graduate level, educators in specific domains (e.g., Software Engineering, Cybersecurity) should consider them in curricular decision-making. Unfortunately, the documentation of the various curricular guidelines and frameworks tends to be lengthy and all-inclusive. This makes it challenging for computing degrees and curricula to stay up-to-date (Janicki et al., 2014; Kang et al., 2020). Studies such as this one help computing education programs, as well as those who write guidelines, make informed decisions about what to prioritize.

2.4 Purpose of This Study

It is important to understand the competencies required on the job to prepare students for not just their first job but a career in computing. This exploratory qualitative study, based on semi-structured interviews of 10 computing managers, addresses the research question,{Citation} "What skills and dispositions do computing managers believe are important to their current position?".

3 Methodology

3.1 Conceptual Framework

For the purpose of this paper, we define competencies as the expertise individuals can demonstrate in professional, educational, social, or other life contexts. The competency construct includes three components: knowledge, skills, and dispositions. In this paper, we focus on:

Skill: Ability to accomplish a goal or perform a task.
Managerial Skills: Management-specific skills used in computing contexts.
Professional skills: Skills used across disciplinary and professional domains.
Dispositions: Attitudes, habits of mind, and internal considerations that impact someone's actions or work.

3.2 Participants

The data included are part of a larger, NSF-funded study on competencies required by computing professionals. Ten participants in managerial roles were selected from 31 who took part in the larger study on professionals in the computing industry (see Table 1). As part of that larger study, a combination of purposeful sampling techniques (Palinkas et al., 2015), including link tracing and criterion sampling (Spreen, 1992), were used to identify participants. Team members sent the request

Table 1 Participants' Academic Background and Employment Information

No	Education	Years in IT	Industry sector	Org size	Job title
1	BS CS, MBA	22	Finance	11,800	Business Relationship Manager
2	BS EE, MS EE, MBA	40	Communication	< 500	Executive Director, Product Dev
3	BS Mathematics, MS CS	41	IS	4	Owner
4	BS CS, MS & PhD IST	4	Marketing	56	Engineering Manager
5	BS CS; MS Computer Apps	14	IT Consultation[a]	> 45,000	Assistant Director of Technology
6	BA Television & Film Production	20	IT Consultation[a]	> 45,000	Associate Director of IT
7	BS CS, MS CS	9	IT Consultation[a]	> 45,000	Associate Director
8	BS MIS	17	IT Consultation[a]	> 45,000	Associate Director
9	BA Physics	23	Finance	< 50	Head of Developer Relations
10	BS CS, MS CS, PhD CS	14	Transportation[a]	> 45,000	Director of Research Operations

[a] These participants are members of consulting groups affiliated with a university but provide consulting services to outside organizations

for participation to contacts in computing and those who could forward it to eligible participants. Respondents were asked to complete a questionnaire, and those who matched the inclusion criteria were selected. Participants were requested to forward the invitation to their acquaintances in the computing industry who met the criteria and might be interested in participating. This was continued until sufficient participants in each job family (e.g., "managerial") were interviewed. For this study, we selected 10 currently serving in management, project management, or product management roles. All 10 participants had prior experience in IT, Software Development, or other computing-related roles. Participant numbers shown in Table 1 will be used to identify quotes from those participants in the results section.

3.3 Data Collection

Hour-long semi-structured interviews were conducted with each participant. Questions relevant to this paper related to what participants do on a typical day, and what skills, knowledge, and dispositions are required on their job. Participants in managerial roles were also asked about hiring practices.

Prior to collecting research data, four pilot interviews were conducted, and researchers refined the protocol (Click here for the final protocol). A simplified question list was sent to participants prior to the interview to review or add notes if they wished to do so. All the interviews were conducted online through Zoom or Microsoft Teams by two team members. Each interview was recorded, transcribed, and cleaned.

3.4 Data Analysis

We used the competency construct as we defined it for our conceptual framework. This paper focused on the skills and dispositions that became our coding hierarchy's primary initial themes. The remainder of the analysis was driven by thematic analysis. This approach follows the general steps: familiarizing yourself with the data, generating initial codes, searching for themes, reviewing themes, defining themes, and reporting the findings (Nowell et al., 2017). In forming codes, we developed ourselves as a "human instrument", based on our own tacit knowledge, prior experiences, and growing understanding of the data (Lincoln & Guba, 1985). We were also informed by existing literature, although we did not use a theoretical framework for lower-level sub-themes and notes.

For this study, Dedoose qualitative analysis software was used for joint coding sessions. Two researchers coded each transcript together, continuously discussing and making notes on the meaning of emerging codes and grouping them under larger emerging themes. Prior coded transcripts were reviewed when new codes emerged along the coding process. After all transcripts were coded, codes were merged, renamed, or reorganized, and excerpts were reviewed again. Codes relevant to three categories (managerial skills, professional skills, and dispositions) were included in this study; knowledge and technical skills, as well as unrelated topics covered in the interview, were not coded. The ten transcripts, including 109,301 words, were

analyzed, and 15 themes (major skill areas) and 148 relevant codes (sub-skills) were generated. The coding structure, along with relevant quotes, is shared in Sect. 4. We have removed non-meaningful utterances such as "um," "like," or adjacent repeated words from the quotes in this paper.

> Where possible, we have used longer quotes to provide a "thick description" and a sense of the participants' voice.
> Thick description" of results presents adequate "voice" of participants; that is, long quotes from the participants or excerpts of interviewer-interview dialogue. Again, a sense of verisimilitude is achieved as the reader can visualize the participant-interviewer interactions and gets a sense of the cognitive and emotive state of the interviewee (and interviewer) (Ponterotto, 2006, p. 547).

3.5 Credibility and trustworthiness

Credibility and trustworthiness (the qualitative equivalents of validity and reliability) were addressed in several ways, as recommended by Lincoln and Guba (1985). Confirmability was in part addressed through the recording and verbatim transcription of the interviews and documentation of methods used. Dedoose kept track of emerging themes and codes, code descriptions, and linking codes to excerpts in each transcription. Credibility was addressed through researcher triangulation (the first three authors conducted the analysis in pairs of two) and peer debriefing (results were reviewed with the fourth author). Trustworthiness was also addressed throughout the process through prolonged engagement with the data, use of a constantly evolving coding framework discussed throughout the coding process, vetting of themes by other team members, and documentation of our process (Nowell et al., 2017).

3.6 Limitations

There are several limitations to this study. Only ten participants were included, with smaller numbers in certain roles (e.g., only two were product managers). Five were from two consulting groups within one larger organization. All ten had technical backgrounds; managers with non-technical backgrounds may have different perspectives. Only interviews were used; it would be ideal to use other sources for data triangulation, such as focus groups, document analysis, or observations. Furthermore, we selected items that were mentioned by at least three participants to report in detail, allowing for "thick description" through rich quotes in some areas; we recognize that even those mentioned by one individual may be important. However, we made a judgment to cut off at those mentioned by over three individuals to meet the length requirement for this paper. Because this is a qualitative study, there is no presumption of generalizability. The alignment between our themes and existing literature on professional skills and dispositions increases our confidence in the transferability of the findings of this study.

4 Results

A total of 148 codes were identified and are reported in three categories: *managerial skills*, *professional skills*, and *dispositions*. The word cloud in Fig. 1 includes all codes to provide a big picture of our data.

4.1 Managerial Skills

A total of 23 managerial skills were identified (Fig. 2) and categorized into four themes (Table 2), related to managing people and projects. More details are reported on each theme in the following sub-sections.

4.1.1 Leadership

Leadership is a big part of all the participants' managerial positions. Leadership relates to skills to maximize the potential of the team and resources toward the attainment of organizational objectives. Each participant mentioned at least two of the sub-skills in leadership. In addition, three sub-skills were discussed by

Fig. 1 Word Cloud of All the Codes

Fig. 2 Word Cloud of Managerial Skills

more than three participants, which are described below: *Have sufficient technical skills and knowledge, adjusting management style to supervisee's personality,* and *resource allocation.*

Have Sufficient Technical Skills and Knowledge. Most participants discussed how "*technical acumen*" [9] allowed them to work with various stakeholders. When working with clients, this enabled them to "*ask meaningful questions and to be perceived by the other parties as being knowledgeable versus being sort of a dope who doesn't know what they're talking about*" [2]. On the other hand, "*when you're talking to developers about the product, if you don't have a fundamental technical understanding of the issues that they face and empathy with them, you're going to have problems*" [9]. All participants had served in technical roles prior to their current managerial role, and several felt this was a strength in comparison to peers without that background.

> *Learn at least a little bit about the [IT] field 'cause... Let's say I have a project manager who has a PMP certification [who] is really knowledgeable for the project manager position, but if he is not good at IT or those... terms and the words. He will have a hard time understanding the developers 'cause those folks are always going to talk in a technical language. If you don't understand that if you're not good at it.* [5]

Adjusting Management Style to Supervisees' Personalities. Half of the participants discussed adjusting their management style to team members' personalities and needs; "*you should not manage people the way you want to manage. You should*

Table 2 Managerial Skills by Theme with Number of Participants and Number of Excerpts (quotes)

No	Managerial skills	Number of participants	Number of excerpts
1	**Leadership**	**10**	**64**
	1) Have sufficient technical skills and knowledge	6	9
	2) Adjusting management style to supervisee's personalities	5	16
	3) Resource allocation	5	16
	4) Future planning	2	5
	5) Recognizing challenges faced by team members	2	4
	6) Keeping track of the bigger picture	2	3
	7) Recognizing capabilities of team as a whole	2	2
	8) Building a good team	2	5
	9) Leveraging power difference	1	2
	10) Considering others' leadership styles	1	1
	11) Create a positive culture	1	1
2	**Project management**	**9**	**35**
	1) Project management (general)	4	8
	2) Managing large and multiple projects	4	5
	3) Prioritization	3	7
	4) Time management	3	6
	5) Stakeholder management	3	4
	6) Recognizing warning flags towards success of a project	2	2
	7) Keeping abreast of work status on a project	1	2
	8) Project and implementation planning	1	1
3	**Hiring & evaluating candidates**	**9**	**30**
4	**Mentorship skills**	**8**	**21**

The number included for each of the four themes is the total number of participants and excerpts for all codes under that theme

manage people the way that they want to be managed" [9] This can be a learning process:

> *Honestly, it's trial and error [process], much like a teacher. You see some students or some employees, and you know you kind of push the buttons until you figure out what buttons make them go right.... You come across more and more personalities, you... tend to pick up on what type of personalities there are and what works.... and you can start to identify those personalities sooner and it's all about setting someone up for success.* [7]

Sometimes, managers adjust their style to unique individuals.

> *We currently have someone on our team that can interact very well with the three or four of us... but he's easily distracted and I think blocking him in the basement so that the butterfly flying by his window doesn't distract him for four hours is probably better.... In that case it's more about his own personal [style]. He works so well*

on the technical side. I'd prefer him not even have to deal with the human side... outside of our team. [6]

Not adjusting your style might impact the entire team, as participant [10] discussed:

There may be someone that's very reserved, very quiet, and they may not speak up either because they don't feel comfortable with it, [or it is] just not their disposition. That's OK… They have a completely different life experience. They have a completely different background, and they're bringing a perspective that you don't have that you could never have. And if you ignore that, then you're really just hurting yourself and you are hurting the team.

Resource Allocation To get the tasks completed efficiently and help the team members grow, half of the participants mentioned it is important to appropriately allocate resources based on team members' capability, career goals, skills levels, and preferred working styles.

The most difficult part of what I do now is... finding the appropriate match of a person to match the technical skill... You know some people are better if you give them a long form of technical tasks. It's going to take six months… at the other end some people require to be spoon fed individual tasks and you must give them six of those a day.… Some people can deal with other human beings quite well... and there's some people that are sharpened and pointy and their personalities and therefore not really a good match to deal with other people. So...constantly juggling what needs to be done with the set of constraints.... that it is probably one of the hardest things I do and also probably one of the most important things because then incorrect choice in one of those goes from something taking five minutes of my day to five hours of my week from trying to soothe personalities on both sides.[6]

4.1.2 Project Management

Project management relates to skills involved in managing tasks to achieve the project goals by using available resources. Almost all participants discussed project management skills, which broke into eight sub-skills. Besides the general references to project management, four were mentioned by at least three participants: *Managing large and multiple projects, prioritization, time management,* and *stakeholder management.*

Managing Large and Multiple Projects. Some participants mentioned that they needed to manage large projects, as well as managing multiple projects at a time. They had to *"switch between multiple projects and multiple sponsors…[and] to bounce in and out of a project"* [7]. Sometimes, *"it's kind of interesting…wear[ing] a lot of different hats on [a] daily basis"* [8], but it is also challenging. One participant proposed a potential professional development training:

I really do think if everybody got a little bit more exposure from at least some level of a project management course where you're just forced to go through

that exercise of understanding how to keep multiple balls rolling at the same time and things like that, I think that would be really helpful.... even if it's a [three-to-] four-week course. [3]

Prioritization Several participants mentioned the importance of *prioritization*. Participant [1] explained,

We always have competing priorities and we have a limited set of resources, so we're kind of helping with prioritizing and doing the resource management at the same time.... I just act as the intermediary for the technology teams or represent them in the business discussions.

Time Management Several participants discussed *time management*, as participant [7] described:

Time management is a big one… finding the time throughout the day to still move everything forward can be challenging… So, time management is a huge skill. [It] is important to push things forward. If you can't manage your time, you will drown in the professional world is what I found.

Stakeholder Management Some participants mentioned their experience in stakeholder management, as described by one participant: *"So in my case, I was managing the business and technology stakeholders, so it did involve a lot of interaction with the business, not just the technology teams"* [1]. Usually, they needed to interact with internal *"project managers, product managers, software engineers"* [10] to get necessary information about the projects, then manage clients' expectations, for example, *"explain to them what it looks like because of the systems and the framework limitation. If you are thinking of implementing this, we might not probably do it because of the limitations of the framework and then they will understand it"* [5].

4.1.3 Hiring & Evaluating Candidates

Almost all the participants were involved in the hiring process. They shared their *hiring* process and discussed how they *evaluate candidates*. The hiring process is diverse, but usually contains both technical and non-technical interviews or activities. Normally, it starts with a phone interview, followed by an in-person interview. But the hiring process might be more extensive (participant [4] mentioned an 11-step process). During the technical interviews or activities, most participants indicated that they evaluated candidates' foundational technical and programming skills but did not expect candidates to have mastered specific technologies or languages, as one [3] explained:

I was less inclined to look for skills that exactly matched what we were doing, realizing that there are so many tools and so many languages and so many areas of expertise...what I would tend to look at is did they have a background in a couple of different programming languages?

Comparatively, participants indicated that experience is most important, as participant [2] shared:

When I was doing interviewing, especially straight out of college people, the thing that was really important to me, more than being that concerned about grades or specific classes, it was what practical experience have you had?... But if they don't have a meaningful amount of practical knowledge, it's to me the risk of bringing them on is extremely high as they just end up with people who are very theoretical and can't get anything done.

In addition to asking questions, some managers reviewed the interviewee's code samples, asked them to do live coding, or had teamwork with the candidate on a real project, as several participants [2,4,5,6,8,9] mentioned. Throughout this process, they evaluated candidates' critical thinking, problem-solving, teamwork, communication, and presentation competencies. They also assessed candidates' attitudes, dispositions, and to what extent they fit the team and organizational culture. They hope to find candidates who are willing to learn, positive, self-driven, intrinsically motivated, passionate, and adaptable to new environments.

4.1.4 Mentorship Skills

Most participants indicated *mentorship* is an important part of their managerial role. They emphasized the importance of assessing their team members' current skill levels and needs and providing proper mentorship. As participant [4] described:

It depends on their level... if I had a junior engineer, [this] looks like me meeting with them on a one-on-one basis weekly. Discussing where they're struggling and where they think they're doing well...I'll spend more time there than I will with a more experienced engineer.

In some cases, they provided direct mentorship: *"[I] like to sit with them line by line, debug the issue, and find out what's the cause of the problem if they're trapped in some of the issues for more than a week"* [5]. In other cases, they pair mentees with more senior mentors. For example, one discussed attending training and returning to train other team members. Mentorship was also important for helping team members gain confidence. They saw their role as helping their team members grow, although they recognized that this could not come at the cost of business goals, as participant [9] explained:

If your team member really wants to do something in React and you're like, hey buddy, sorry we're actually not working [with] React right now in this project.... I want you to get this experience... Why don't we find a way to do this at a hack fest or send you to a conference where you could learn this… you want to align the company's goals with the employee's goals, but sometimes it's kind of shifting things around and being creative about those solutions…. I want developers to be happy.

Several participants discussed the importance of understanding team members' goals and providing opportunities to develop skills needed to move to a position

they enjoy, or to the next stage of their career. For managers, the ability to understand employees' career goals is a learning process, as participant [3] discussed:

> *You have to learn how to be a coach. You have to learn how to guide people and talk them through what do they want out of their career. In a lot of engineering management work that kind of takes a back seat, which I think is unfortunate because I think understanding where people want to go with their career is really, really important, and it's definitely... something that, at least in the experiences I had across multiple companies, was not well understood.*

Participant [5] explained that understanding employees' goals should start early.

> *Nobody should come into this field without their goal. Even … some of the freshers who joined our company as an intern... I normally keep walking into the organization [and] whenever I see a new person, I stop by his desk and say, 'hey how's everything and you know what are you doing?'*

Participant [2] emphasized the need to have reasonable expectations:

> *It may be something where you really need to do some career development work with them and get them to a better skill level but beating them up about where they're at today generally isn't a useful thing to do.*

4.2 Professional Skills

Professional skills reported here are skills needed by all professionals that were highlighted by the managers in this study. Eighty-five professional skills emerged (Fig. 3) and were grouped into six main themes (Table 3). Detailed information on these six categories is reported below.

4.2.1 Communication

Communication is the central theme of professional skills (Fig. 3). All participants discussed at least two of the 27 communication sub-skills (Table 4). When participants mentioned *communication* but did not describe a specific sub-skill, we coded it as *general communication skills*. All the other sub-skills were categorized into three themes, *tailoring the message*, *verbal communication,* and *written communication,* which are discussed below.

Tailoring the Message *Tailoring the message* highlighted the importance of delivering appropriate information when communicating with different audiences, in different contexts, and for different purposes. Almost all participants mentioned the importance of "*tailoring what you say*" [2] in communication based on audience, situation, or purpose. Three sub-skills were mentioned by at least three participants.

Half of the participants emphasized the importance of *tailoring language to the audience*. As participant [9] explained, *"I talk differently to sales and marketing than I do to engineering managers… you have to assess what people need to know."*

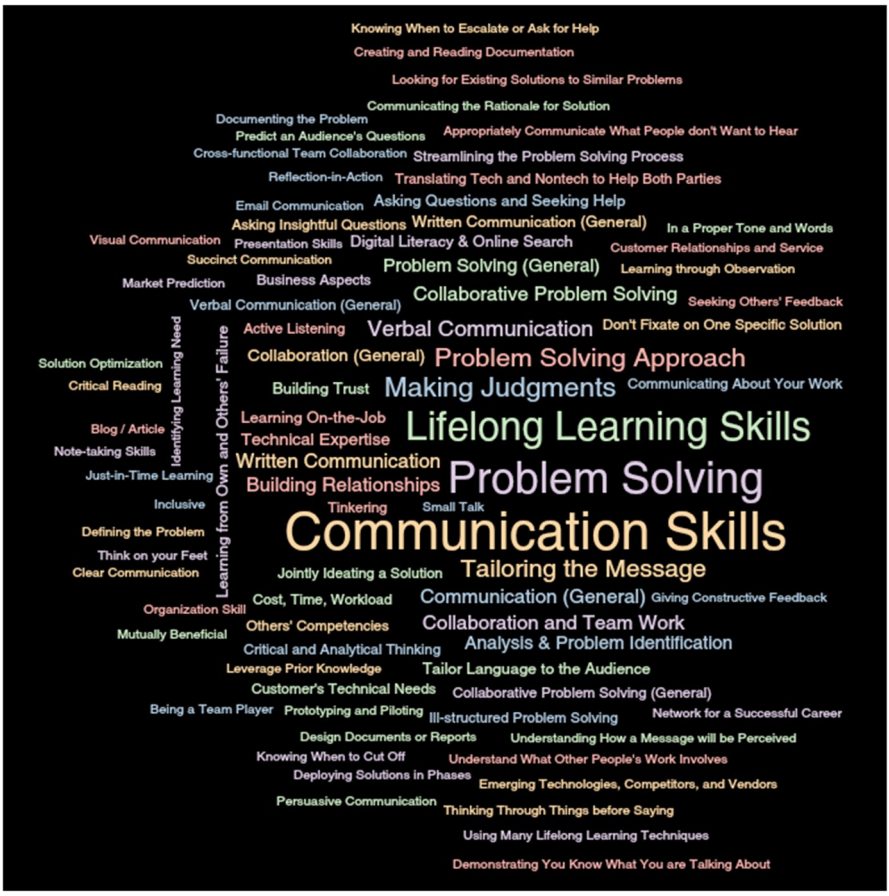

Fig. 3 Word Cloud of Professional Skills

Table 3 Professional Skill by Themes with Number of Participants and Number of Excerpts (quotes)

No	Professional skills	Number of participants	Number of excerpts
1	Communication skills	10	88
2	Problem-solving	10	69
3	Lifelong learning skills	10	61
4	Building relationships	7	18
5	Collaboration and teamwork	7	16
6	Making judgments	6	35

Table 4 Communication Skills by Theme with Number of Participants and Number of Excerpts (quotes)

No	Skills	Number of participants	Number of excerpts
1	General communication skills	6	18
2	Tailoring the message	9	29
	1) Tailor language to the audience	5	8
	2) Translating tech and non-tech to help both parties	5	5
	3) Appropriately communicate what people don't want to hear	3	3
	4) Understanding how a message will be perceived	2	3
	5) Succinct communication	2	3
	6) Predict an audience's questions	2	2
	7) Knowing when to cut off	1	2
	8) Demonstrating you know what you are talking about	1	1
	9) Persuasive communication	1	1
	10) Thinking through things before saying	1	1
3	Verbal communication	7	24
	1) Verbal communication (general)	4	5
	2) Communicating about your work	3	5
	3) Active listening	2	4
	4) Asking insightful questions	2	4
	5) Presentation skills	2	3
	6) Clear communication	2	2
	7) Small talk	1	1
4	Written communication	6	17
	1) Written communication (general)	5	7
	2) Email communication	3	3
	3) Design documents or reports	1	3
	4) Blog/article	1	2
	5) In a proper tone and words	1	1
	6) Visual communication	1	1

The number included for each of the four themes is the total number of participants and excerpts for all of the codes under that theme

Half of the participants told us that they serve as *translators between technical and non-technical stakeholders*, as participant [7] described:

> *A business needs a technical task and [I have to] be that bridge. I have found that meetings can be wasted if you're talking in two different languages... and that can cause frustration and... cause a delay in our schedule because a lot of times...the external client will present a need and it's misunderstood on the technical side and so that development effort is wasted.... You know, everyone knows what their need is, but they may not know how to explain it correctly, and so being able to efficiently communicate with both sides, I think it's huge in my role.*

Several participants said it was challenging to *appropriately communicate what people don't want to hear*, as participant [4] shared:

> *One thing that was always hard for me was starting out with telling people things they didn't want to hear and knowing they didn't want to hear it."* And their strategy is *"being radically candid with people, so not being a jerk necessarily, but just being able to say, hey, this is the reality of the situation.*

Participant [2] shared their strategy to "*try to present things in a positive way… in a way that makes it clear that the analysis has been done thoughtfully*". Participant [5] described this strategy as "politics":

> *How to handle the thing 'cause they are non-technical people, they can say, 'hey I want ... my site to work like this.' Well, you cannot just say no to them. They're paying you, right? But at the same time, you also have to make sure that it doesn't make a burden to your team. So, you need to play politics. You need to be better at communication skills.*

Verbal Communication Most participants discussed the importance of verbal communication, either in general or using strategies including *active listening*, *asking insightful questions, presentation skills,* and *clear communication*. Most participants mentioned that they needed to communicate verbally with either internal teams to "*catch up on the status of the project*" [8] or external clients to proactively "*provide those updates*" [7]. This relates to speaking, listening, and careful questioning in a bi-directional communication; participant [7] explained,

> *I'm being able to pull out requirements from just a casual conversation, or at least a presented conversation. Pulling out those requirements and not making that an established process. But being able to pull those requirements organically, I think that's a good summation of that. Being able to organically pull out requirements is a huge, huge benefit there.*

Written communication Most participants discussed the importance of *written communication*, either in general or in reference to types of written communication, such as *email, design documents, reports,* or *blogs.* Participants also mentioned *visual communication* and writing in *a proper tone and words.* For example, a big part of the participant [9]'s job was "*writing documentation, writing tutorials, [and] writing some soft leadership pieces that are about the technology in general,*" and they explained that: "*the ability to write coherently and cogently, and not just short blips like emails, but you know, 2000, 3000, 5000 words is important.*"

4.2.2 Problem-Solving

Problem-solving is another central theme among professional skills. These are organized based on themes arising from the data rather than a theoretical framework, although some code names are informed by other literature. All participants discussed more than one of the 18 problem-solving skills (Table 5). Besides *general*

Table 5 Problem-solving Skills by Theme with Number of Participants and Number of Excerpts (quotes)

No	Skills	Number of participants	Number of excerpts
1	**General problem-solving**	**6**	**15**
2	**Problem-solving approach**	**8**	**32**
	1) Analysis & problem identification	4	13
	2) Don't fixate on one specific solution	3	6
	3) Defining the problem	2	2
	4) Deploying solutions in phases	2	2
	5) Reflection-in-action	2	2
	6) Prototyping and piloting	2	2
	7) Looking for existing solutions to similar problems	1	2
	8) Communicating the rationale for solution	1	2
	9) Solution optimization	1	1
3	**Collaborative problem solving**	**5**	**18**
	1) Collaborative problem-solving (general)	4	6
	2) Jointly ideating a solution	3	6
	3) Streamlining the problem-solving process	3	4
	4) Documenting the problem	1	1
	5) Seeking others' feedback	1	1
4	**Ill-structured problem solving**	**3**	**4**

The number included for each of the four themes is the total number of participants and excerpts for all of the codes under that theme

problem-solving (problem-solving mentioned but without indication of a specific sub-skill by most participants) and *ill-structured problem-solving* (mentioned by three participants), all the other sub-skills were categorized into two themes: *problem-solving approach* and *collaborative problem-solving*.

Problem-solving Approach *Problem-solving approach* includes skills needed in different stages. Most participants shared stages of their problem-solving approach, including *defining the problem, analysis & problem identification, prototyping and piloting, deploying solutions in phases,* and *reflection-in-action.*

Some talked about the importance of *analysis and problem identification*; "*[The] first step of problem-solving is trying to understand the problem and the most difficult part of it is figuring out what is the thing that you're actually trying to do, not how I can start writing software."* [10].

Several participants emphasized that *don't fixate on one specific solution* because "*the first solution isn't the correct solution*" [7]. Another explained their process: "*I think that sort of process of taking the idea, of putting it down, iterating that, getting it to a point, and you may throw it away*." [10].

Collaborative Problem-solving *Collaborative problem-solving* highlights the role of collaboration in problem-solving. Half of the participants discussed the value and

importance of solving problems collaboratively. Participant [10] emphasized that people can become frustrated while working on their own, and it is important to recognize that by "*pushing through that and working, collaborating with other people, you can get a lot of good results."* Participant [4] highlighted collaboration as an important ability to *"listen to other people's ideas and weigh them against your own and figure out what might be the best path forward."*

Several participants shared their experience *in jointly ideating a solution*. As participant [10] said: *"A lot of the discussions that we have are at the very beginning of projects and in the ideations part – just sort of, is this even possible?"* They described an experience that was "*an exemplar of what could be when you, when you collaborate in a healthy way with other people*": initially eight individuals met to decide "*on an entire architecture*" in "*a grueling set of meetings,*" then divided up the tasks to work independently for a week. They marveled that *"with just documentation that was in our heads, committed them and it worked,*" allowing them to smoothly transition to further joint planning and development work." Participant [10] further emphasized,

> *In the opportunities where we have to be able to take all the different perspectives and coalesce them together....That helps make people feel more included, and it usually ends up... yielding a better result.*

Some participants stressed the importance of *streamlining the problem-solving process* collaboratively with the team and relevant stakeholders. Participant [1] said it was essential to *"make sure everybody signs off"* before the team members begin working on projects. Participant [9] shared *"you have to get the stakeholders in your organization around it and that could be even people outside your organization,"* because the problem might be redefined or even *"[go] away"* when they got involved.

Ill-structured Problem-solving Several participants discussed *ill-structured problem-solving*, as problems are often not clearly defined and there is not one correct solution: *"Sometimes they may not give you enough information or sometimes may not understand what the entire workflow is"* [1]. Participant [10] described this as *"more of an anti-skill… and this is something that happens in computing a lot, not relying on specific knowledge of specific technologies as a crutch for problem-solving."* Participant [2] described a difficult situation in which a technical problem, not caused by his team, needed to be fixed immediately:

> *[Some problems] were really time bound...An example of that is a Wi-Fi network in a sports and entertainment arena that needed to be working properly for the NCAA Basketball tournament. Well the tournament is going to happen on the day it's going to happen whether you've got it done or not, and if it's not done, it's really going to be an ugly situation. The pressure of getting it and analyzing what the problem was [and] coming up with a solution and getting it done on a specific time frame and this involved it. And you know doing construction work so there were contractors involved in getting them lined up to do it. Keeping the customer aware of what was going on and convincing them that we actually had the ability to solve the mess that we that these contractors had created previously.*

4.2.3 Lifelong Learning

Lifelong learning includes learning skills needed throughout the participants' professional experience. All participants mentioned at least two of the 15 lifelong learning sub-skills in Table 6. The sub-skills that were mentioned by at least three participants are described below.

Digital Literacy & Online Search Most participants shared learning strategies that begin with effective online search skills. All of them mentioned Google; as participant [3] said: *"Google is my friend."* Participant [6] also emphasized that *"being able to google something is one of the more important things, and knowing how to do that… can be a huge difference in what you return,"* and described techniques that they use to improve their search results.

Learning On-the-Job Half of the participants shared their experience of *learning on-the-job*, which was a necessary and natural component of their roles – especially because their role continued to involve some level of technical work and/or deep understanding of technical problems and solutions. Participants commonly *"learn by doing"* [8] in order to "*apply theoretical learning to practical experience*" [1]. There is always something new to learn, as participant [9] explained: "*every organization I've ever been part of, you have to give speed on processes and people and the codebase. You're not walking into a greenfield development 95% of the time, so you have to learn."*

Table 6 Lifelong Learning Skills with Number of Participants and Number of Excerpts (quotes)

No	Skills	Number of participants	Number of excerpts
1	Digital literacy & online search	7	9
2	Learning on-the-job	5	7
3	Asking questions and seeking help	5	7
4	Tinkering	4	6
5	Learning from own and others' failure	3	7
6	Critical and analytical thinking	3	6
7	Leverage prior knowledge	3	3
8	Identifying learning need	3	3
9	Just-in-time learning	2	3
10	Learning through observation	2	3
11	Emerging technologies, competitors, and vendors	2	2
12	Think on your feet	2	2
13	Note-taking skills	1	1
14	Creating and reading documentation	1	1
15	Using many lifelong learning techniques	1	1

Throughout these sub-skills, participants mentioned using a variety of resources for learning (e.g., in-person or online courses, trade journals, blogs)

Asking Questions and Seeking Help Half of the participants highlighted the skill of *asking questions and seeking help from others*. Participant [4] shared that they preferred "*asking people like 'how did you learn this?*'" when they were given something new to work on. Participant [2] said:

> *A lot of it is picked up through asking questions…I try to ask a lot of questions of vendors. I try to cultivate contacts in my own company or elsewhere that I think are really knowledgeable, and also the people who are capable of understanding… of explaining something in a way that's understandable.*

Tinkering Some participants described a common habit of creating projects for the sole purpose of learning technical skills. As participant [6] mentioned, this was "*one of the things I've seen in the most successful people that aren't afraid to tinker with stuff and usually have their own private space in which they play with new stuff that they are interested in.*" Participant [9] shared their own experience:

> *I honestly think software is one of the greatest things, because you can just with a lot of different kinds of pieces, you can just download something and fiddle around with it. So that's a really important way to learn… I had a side project for about 10 years that was a source of a lot of learning for me.*

Learning from Own and Others' Failure Several participants emphasized the importance of *learning from one's own and others' failure* beginning with admitting the failure As participant [10] pointed "*admitting failure should be positive; that's the first place you gain knowledge.*" Participant [9] added: "*realize that you're going to make mistakes and try to make them only once.*" Participant [8] said this is a natural learning part of the learning process; "*You know core concepts, but sometimes it takes like physically doing it and learning from mistakes or issues that arise.*"

Leverage Prior Knowledge Several participants discussed the importance of *leveraging prior knowledge.* Participant [9] recommended that people should "*build analogies between what you've seen in the past and what the person is trying to accomplish*". Participant [4] shared their story:

> *I never used React, which is a JavaScript framework, but I've used other JavaScript frameworks that are similar to it. So the way I started there was looking at code. It's still within the company and how we're using it. And trying to find the similarities from what I had already done, so you know what similar here in this. In this you know it's a single page application. Or a JavaScript framework what's similar to Vue, like I've done Vue before so you know what similarities are there? What patterns can I recognize in the code here? The other side is I literally went and found a Udemy course that talked through, literally walked me through creating from scratch a React NestJS application so that I could once again find the things that are familiar to me and find what's different so that I can assimilate all of that into 'how do I approach developing in this new technology?'*

Identifying Learning Need Some participants highlighted that it was important to identify what to learn before diving into it, as participant [3] said: "*You gotta start asking questions right? … the ability to be able to dig in and ask critical questions up yourself. What am I trying to do? What do I need to know?*".

4.2.4 Building Relationships

Building relationships includes skills regarding building connections with others. Most participants emphasized the importance of building relationships (Table 7), and *building trust* is the central one.

Most participants pointed out the importance of *building trust* among all partners, including team members, clients, and project stakeholders. As participant [1] shared: "*the biggest thing is building those relationships, building trust between the various partners*". Participant [10] mentioned that it takes time to build trust: "*It's just about building trust over time, and it's little moments like that they're being heard and that they're feeling respected and that they're contributing equal parts to the solution*". Participant [9] said "*the easiest way to build trust is to always do what you say you're going to do".*

4.2.5 Collaboration and Teamwork

Collaboration and teamwork skills related to working with people within or across departments or teams. Most participants mentioned at least one of five collaboration skills (Table 8).

Collaboration is important especially when work needs to be completed across either internal or external teams: "*If you can't work with other people, you limit yourself severely in a professional environment*" [7]. Participant [10] discussed how to create a culture of collaborative:

> *Being able to communicate an ethos or philosophy for the organization and try to get everyone on board… trying to understand where they are and then meet everyone in a middle spot...You're willing to compromise shows [sic] people that it's a collaborative environment. It's not a top down. You're leading not bossing them around.*

Table 7 Building Relationships Skills with Number of Participants and Number of Excerpts (quotes)

No	Skills	Number of participants	Number of excerpts
1	Building trust	6	7
2	Customer relationships and service	1	3
3	Understand what other people's work involves	1	3
4	Inclusive	1	2
5	Mutually beneficial	1	2
6	Network for a successful career	1	1

Table 8 Collaboration and Teamwork Skills with Number of Participants and Number of Excerpts (quotes)

No	Skills	Number of participants	Number of excerpts
1	Collaboration (general)	4	8
2	Organization skill	2	2
3	Cross-functional team collaboration	2	2
4	Giving constructive feedback	1	1
5	Being a team player	1	1

4.2.6 Making Judgments

Making judgments highlights the skills needed to make strategic decisions. Most participants shared at least one of the eight sub-skills in *making judgments* (Table 9).

Technical Expertise Some participants highlighted the importance of *technical expertise* in *making judgments,* including team members' "*technical capability to do something*" [2], *"technology selection"* [9], and technical solutions, as participant [8] shared:

> *We help try to bring in research and evaluate new products for clients, so we're always looking at emerging technologies and trying to figure out what's the best that's going on in the field. How can this emerging technology help our client? And then how can this in turn help us deliver a product to them that meets their need?*

Cost, Time, Workload Several participants shared they always needed to balance cost, time, and workload in *making judgments* to determine which technical solution to proceed with. As participant [2] shared: "*It's really easy for people to fall in love with some technical thing and go chasing something that's technically cool and worth pursuing or interesting to pursue, but doesn't actually have a path to being profitable."* Participants also explained that sometimes it is not worthwhile fulfilling a request, because the monetary or time cost is too high.

Table 9 Making Judgments Skills with Number of Participants and Number of Excerpts (quotes)

No	Skills	Number of participants	Number of excerpts
1	Technical expertise	3	11
2	Cost, time, workload	3	5
3	Business aspects	2	5
4	Others' competencies	2	5
5	Customer's technical needs	2	4
6	Market prediction	1	2
7	Critical reading	1	1
8	Knowing when to escalate or ask for help	1	1

4.3 Dispositions

Dispositions represent the beliefs, attitudes, or mindsets participants highlighted as important for their professional experience. Again, these are organized based on themes arising from the data rather than a theoretical framework, although some code names are informed by other literature. The names and organizations or sub-themes are heavily influenced by the NRC framework (National Research Council, 2012). Thirty-seven dispositions were identified, as shown in the word cloud in Fig. 4. These were categorized into five themes (Table 10).

4.3.1 Intellectual Openness

Intellectual openness includes a group of dispositions that indicate openness, flexibility, or willingness to deal with people or tasks. All the participants mentioned at least three of the 9 dispositions in intellectual openness. Three or more participants highlighted the following five dispositions.

Adaptability/Flexibility Most participants emphasized the importance of being flexible and adapting to the situation. As participant [3] explained, *"it's the people that can adapt quickly that are going to be able to jump into that corporate environment and really hit the ground running."* They emphasized that someone in this field needs to be *"open to anything that's thrown at him"* [3] and sufficiently flexible in *"understanding when you're going down a path that's not going to lead to success and getting off that path and finding another way quickly"*[2].

Fig. 4 Word Cloud of Dispositions

Table 10 Dispositions by Theme with Numbers of Participants and Number of Excerpts (quotes)

No	Dispositions	Number of participants	Number of excerpts
1	**Intellectual openness**	**10**	**45**
	1) Adaptability/flexibility	8	11
	2) Being open to critical feedback and failure	4	9
	3) Being passionate	4	5
	4) Willingness to take on a challenge	4	5
	5) Being open-minded	3	5
	6) Willingness to ask for help	2	4
	7) Managers' passion to do technical work	2	2
	8) Being curious	1	2
	9) Diversity Equity and Inclusion	1	2
2	**Collaborative mindset**	**10**	**23**
	1) Blending into the organization/team culture	3	5
	2) Being helpful	3	3
	3) Being sociable	2	3
	4) Willingness to speak up	2	3
	5) Empathy	2	2
	6) Valuing communication and collaboration	1	3
	7) Ability to navigate social dynamics	1	1
	8) Independent	1	1
	9) Professionalism	1	1
	10) Willingness to delegate	1	1
3	**Lifelong learning orientation**	**10**	**20**
4	**Positive core self-evaluation**	**9**	**28**
	1) Self-awareness	4	9
	2) Self-efficacy	3	4
	3) Patience	3	4
	4) Work-life balance	2	3
	5) Ego regulation	2	2
	6) Self-management	2	2
	7) Self-identity	1	2
	8) Perfectionism	1	1
	9) Resilience	1	1
5	**Conscientiousness**	**8**	**30**
	1) Being self-driven/intrinsically motivated	7	16
	2) Perseverance or tenacity	3	5
	3) Positivity	3	4
	4) Work ethic	2	5

The number included for each of the four themes is the total number of participants and excerpts for all of the codes under that theme

Being Open to Critical Feedback and Failure Some participants mentioned that being open to critical feedback and failure is beneficial for both individual and team growth of both their own and the team. As participant [10] shared:

> *It's much wiser to learn from your own and other people's [mistakes] because the wealth of knowledge is so much larger. But you have to be OK, both sharing your mistakes with other people, and also, they have to be comfortable enough to share them with you. So that was a big sort of, you know, growth element.*

Participant [7] also pointed out that being open to criticism is challenging:

> *Being able to accept feedback. Sometimes there are challenges with, you know, just because something worked doesn't mean it's the correct solution. A solution isn't always the right solution, even though it's technically correct. Maybe that's not what is needed at this time, so being able to accept criticism.*

Being Passionate Some participants said "*being passionate"* about the work they do is essential for their own growth. They also look for this in team members and job seekers. People with passion go beyond completing required tasks; they enjoy exploring and having fun throughout the process. As participant [2] shared that *"it was really kind of fun…enjoyable"* throughout *"a couple of months' worth of work"*.

Willingness to Take on a Challenge Some participants valued *willingness to take on a challenge,* and shared how it helps both themselves and other team members. Participant [4] shared:

> *Not be afraid to step in to something you've not done before... to say "OK, well, you know the tool I need to solve this problem is not one I've used before, so I'm going to go learn how to use that tool." So there's a little bit of lack of fear there and a lack of fear of failure is probably the way I would describe it because you have to be OK with getting out wrong. Otherwise, you'll take no steps forward, period. So that that's probably what helped me in my career more than anything is just not being afraid to fail.*

Being Open-minded Several participants shared the importance of *being open-minded;* "*I think the biggest one is having an open mind. Not being set in a particular worldview or position, being comfortable saying that you don't know*." [10]. But sometimes it is challenging, as participant [1] shared: "*being non-judgmental, because I do see unfortunately that even …very young people …come with a lot of preconceived notions about people."*

4.3.2 Collaborative Mindset

All participants discussed at least one of the 10 dispositions under the *collaborative mindset,* which they also look for in new hires. Three participants pointed out that having a *helpful* attitude impacts others. As participant [8] shared: *"People that are willing to…help others, lend a listening ear, to be there when there's hard times or there's problems to solve, those are always very good qualities"*. When discussing

hiring and evaluating candidates, three emphasized the importance of *blending into the organization and team culture*, which is an essential part of evaluating candidates (as we discussed in the Hiring & Evaluating Candidates section).

4.3.3 Lifelong Learning Orientation

While life-long learning skills were discussed in a prior section, an orientation towards continuous learning is a prerequisite to learning and effectively utilizing those skills. A lifelong learning orientation drives participants to learn for immediate work needs, to keep themselves current, and for self-growth. While self-directed learning might be in aid of a specific project, for managers it more frequently had the goal of keeping up to date with technology. As one stated, *"We are in IT. You know, the field is changing every day. So if you want to stay on top of it, just learn everything."* This allowed them to communicate with and manage technical staff and assess the feasibility of technical solutions. Participants were not only willing but passionate about engaging in lifelong learning.

> *There was a passion so I would go home and find some project so it might be like installing a new Linux distribution... Or maybe I'll just like hey, I really want to do this new website or project that I would think would be fun and I would just go learn something just to do something fun.*[8]

4.3.4 Positive Core Self-evaluation

Positive core self-evaluation represents positive self-perceptions essential for participants' professional experience. Almost all participants highlighted at least one of nine dispositions. At least three emphasized the following aspects.

Self-awareness Some participants discussed the need for themselves and their team members to be self-aware. *"Having enough awareness and introspection to know what your strengths are and what your weaknesses are, and how to leverage those strengths and weaknesses relative to your team, whether they're at an engineering level or a managerial level"* [3]. *Self-awareness* is beneficial in many ways *"It's a way of examining yourself, understanding how you learn, how you assimilate information, how you interact with others…how you problem [solve]"* [10].

Self-efficacy Participant [2] thought *self-efficacy* was "*about your ability to kind of single handedly get your head around the problem"*; While you have "*enough information that it was completely doable if you had reasonable capabilities, but it wasn't easy.*" They described a particular experience that was *"kind of a turning point. I really like this stuff and I'm pretty good at it. And then I was able to figure these things."* Some other participants shared their experiences in developing *self-efficacy*. You need to "*dive into one thing*" [5], "*don't be afraid of errors*" [5], "*get over your fear*" [5], and accomplish it because "*the perfect is the enemy of the good, so implementing something is better than nothing*" [10].

Patience Several participants discussed the importance of patience. Participant [10] shared that being patient is a disposition you need to consciously develop or learn: "*they changed their mind six times and you get frustrated, and learning patience is very important.*" Participant [1] pointed out that *"a lot of patience is required"* when your job role is not *"well understood"*. Participant [5] stressed the role of patience in mentorship:

> *If you were going to mentor someone on being a mentor...what would you teach them? Or tell them that they need to focus on? I would say 'be patient... That [mentee] is pulling everything he has to learn that thing, so you need to be patient and teach him.'*

4.3.5 Conscientiousness

Conscientiousness indicates the importance of taking responsibility for one's work, especially in difficult situations. Most participants talked about four aspects of *conscientiousness*. Three or more highlighted the following.

Being Self-driven/Intrinsically Motivated. Most participants discussed the need to be self-motivated, which some tied to work ethic. As participant [7] shared, "*if the task isn't defined correctly… defining it or getting it defined for yourself. You know, just not being proactive instead of reactive. I think that is the best way to describe work ethic."* Participant [8] emphasized a connection between *being self-driven* and success:

> *Always be willing to go above and beyond because you buy into the vision of the company... anybody that's willing to put extra time in going above and beyond [is] usually very successful. Just because, you know, you don't want someone who says, 'well that's not my job. I'm not doing it.'*

Perseverance or Tenacity Although only several individuals explicitly discussed the importance of *perseverance* or *"grit"*[10], this disposition also implicitly underlay many stories shared across participants. Participant [9] described in vivid terms:

> *I actually remember one time when I was a CTO in that startup and I ran into this problem that I had no clue how to solve and I remember just lying on the ground miserable because there was no one else I talk to who had the all the contacts in their head and I just keep beating my head against the wall trying to figure out how to solve this particular issue... I had to find ways to stay motivated to kind of solve that kind of really tough problem.*

Participant [9] went on to explain that he also felt the need to find strategies to persevere when he was "bored". "I found ways to stay motivated by improving the code in ways that the company didn't care about, but made it feel better for me" [9]. Participant [6] shared an experience that required "tenacity":

I was working probably 12 hours a day at that point trying to get things fixed...I think never really getting down on yourself if you don't know how to do something. Because if you just give up, nothing has been gained or achieved...I think there's nothing that you can't eventually figure out. It is just finding the way to the keys to unlock the doors.

Positivity Several participants mentioned *positivity,* which included demonstrating a "*good attitude*" [8] or a "*can-do attitude*" [1]. Participant [7] intertwined this with *being self-driven*: *"Just daily positivity. Making yourself available, being self-driven, being self-motivated."*

5 Discussion

5.1 Career Path from Technical Degree to Manager

One typical career path to becoming a manager of computing staff is to begin with educational and work experience in computing. This is consistent with the definition of managers in computing as given by the U.S. Bureau of Labor Statistics, which describes a manager in the computing field as someone who holds a bachelor's degree in that field and indicates that some organizations prefer a management-oriented graduate degree as well, such as a Master in Business Administration (MBA), or a degree in Management information systems (MIS) (U.S. Bureau of Labor Statistics, 2022). A manager is responsible for "managing technical team members" as well as "managing technical development (pushing product design, driving the development cycles, establishing strategy, and helping solve technical challenges)" (Exponent, 2022).

This paper looks specifically at computing managers who have worked in technical roles. Most had a degree in a computing-related field, although several who graduated decades ago had degrees in Electrical Engineering, Physics, or Mathematics, probably because there were no distinct computing degrees at that time. Most of these had a graduate degree in computing, although a few also had MBA degrees. Their technical backgrounds allow them a useful perspective not only on manager competencies but also on the technical aspects of the job – allowing them, for example, to serve as mentors for computing staff.

While new graduates typically do not immediately enter managerial roles, bachelor's degrees can begin to prepare students for a career trajectory that moves towards management in the future, should they desire to do so. For example, a typical path to a managerial track for technical staff moves from junior to senior computing professional up to lead (managing mid-sized teams) and then manager (who might manage multiple teams) (Exponent, 2022).

Although new graduates may not require these skills in their first job, one participant suggested that programs add course activities to guide students to consider potential career paths in management.

You need to be positioning yourself fairly early in your career to get to where you want to be or you won't be able to get there. So if ...you recognize that you

really prefer to move towards management, then you need to think about early on 'what do I need to do to make that happen and do it?' [2]

Discussion of possible career paths can be integrated throughout a degree program (aligning with IT2017's competency sub-domain employability skills and careers in IT (Sabin et al., 2017) and ABET computing accreditation criteria "principles and practices of IT project management" (ABET, 2017). Although not all computing professionals wish to enter management, within a few years of their career, most will begin mentoring and may be involved in interviewing new applicants. Many professionals need to interface with users, participate in discussions about users and requirements with other stakeholders, and prioritize their work. They would benefit from acquiring IT project management skills during their undergraduate work.

5.2 Core Managerial Skills

This study found four core managerial skills, each of which involves interactions with people and decision-making. These included leadership, project management, hiring and evaluating candidates, and mentorship skills. This is consistent with other collections of competencies as employees move through levels of experience and into management roles. For example, Skills Framework in the Information Age (SFIA) is an employer-led competency framework (SFIA Foundation, 2021). For those with higher experience levels, SFIA includes people management, stakeholder management, and relationship engagement management. It also includes the behavioral factors of leadership, planning, delegation, decision-making, and influence.

Developing project management skills is particularly important and feasible during an undergraduate degree experience. Curricular approaches to project management give students experience not only with the individual contributor role but also with the managerial role. In a course setting, a managerial role may be assumed by a single student, may be rotated among students, or may be exercised by the course instructor alone (Kirk et al., 2022). Such scenarios can benefit from understanding what an IT managerial role means in the workplace, especially when it relates to the skill set and dispositions revealed by our study. In their study, Kirk et al. (2022) indicated that team self-management ("ability to self-manage effectively") requires communication, coordination of project tasks (e.g., version control and responsibilities), and clarity related to project activities and structure (p. 150). Individual students must also demonstrate commitment, expertise, maturity, and availability. If students do not have these competencies, they risk non-completion of the project. The authors stress that a lack of adequate educational support to be successful in such a project will lead to students who are not prepared for the workplace.

Leadership, evaluation of others, and mentorship skills can also be fostered during undergraduate experiences. For example, self-and-peer evaluation during team projects can help to foster the ability to evaluate others and provide useful feedback when instruction and scaffolds are given (Huang et al., 2022; Richmond et al., 2016). Similarly, students can mentor junior or same-level peers (Li et al., 2021; Liu & Li, 2014).

Some of the skills we listed under leadership can also begin to be developed. For example, the most frequently mentioned finding was "have sufficient technical skills and knowledge." So, even for students intending to eventually move to a leadership role, solid technical foundations are required. In addition, ABET's student outcome, "Function effectively as a member or leader of a team engaged in activities appropriate to the program's discipline" in its Criteria for Accrediting Computing Programs (ABET, 2023), indicates that programs can and should require at least some students to develop management and leadership skills (p. 7).

The second most mentioned finding under leadership is "adjusting management style to supervisee's personality." This requires interpersonal skills and the disposition of empathy, which also can and should be developed in an undergraduate experience (Sutherland, 1986). Such skills require role modeling and reflection, which need to be purposefully included in a curriculum. Empathy can also be furthered through exposure and meaningful communication with diverse people with varying backgrounds, personalities, and majors – something that should be encouraged during students' time in college. Service learning may also be an excellent approach to encourage the development of this disposition.

5.3 Professional Skills

Managers interviewed highlighted 85 professional skills, categorized into six categories: communication, problem-solving, lifelong learning, building relationships, collaboration and teamwork, and making judgments. These types of competencies have been shown to be important across industries and roles (Hart Research Associates, 2018; Project Lead the Way & Burning Glass Technologies, 2019)– although often under other names such as "soft skills," "twenty-first century skills", "transportable skills," etc. These findings are consistent with literature focused on skills required by hiring managers, directors, supervisors, and managers (do Vale et al., 2018; Shet & Pereira, 2021). Professional skills are also discussed in literature about computing professionals, which frequently identify communication, collaboration, lifelong learning, critical thinking, and problem-solving as even more important than most technical skills (Exter et al., 2018; Hollister et al., 2017; Lundberg et al., 2018; Schirf & Serapiglia, 2017). SFIA's Information Age skills framework mirrors this by including the "behavioral factors": communication, collaboration, problem-solving, and "learning and professional development," which aligns with lifelong learning. Each of these behavioral factors includes levels of responsibility beginning with those aligning with individual contributor positions and going all the way up to complex, collaborative skills that are appropriate to managers and leaders (SFIA Foundation, 2021).

Our findings align with those of the cited studies, which are derived from empirical research from the industry based on data from interviews and surveys of managers/professionals themselves, as well as job advertisement analyses. Many of these studies also identify gaps between what is seen as important in industry and the skills demonstrated by recent graduates, despite efforts to include these skills in computing education programs, as recommended by the IT2017 (Sabin et al.,

2017) and CC2020 (CC2020 Task Force, 2020) curricular guidelines. In fact, some of these skills are also required for ABET accreditation. ABET Criteria for Accrediting Computing Programs (2023 – 2024) requires integrating professional skills into computing curricula to enhance students' learning outcomes. For example, the Criteria for Accrediting Computing Programs include the student outcomes "Communicate effectively in a variety of professional contexts"; "Function effectively as a member or leader of a team engaged in activities appropriate to the program's discipline," which aligns with collaboration (and moves towards the development of managerial skills); and "analyze a complex computing problem and to apply principles of computing and other relevant disciplines to identify solutions," which aligns with problem-solving (ABET, 2023).

Yet, studies show that recent graduates may not be sufficiently skilled in some professional skills (Exter et al., 2018; Hart Research Associates, 2018; Project Lead the Way & Burning Glass Technologies, 2019; Schirf & Serapiglia, 2017). While many of these skills may be taught in "gen-ed" classes (such as standalone English and Communication classes), research has found that the transfer of skills is encouraged when a learning task is similar to the performance context, as memory is dependent on the environment in which learning occurs (Imuta et al., 2018; Smith & Vela, 2001). It is important to also embed the development and assessment of these "transferable" skills into computing courses, especially where the experience ties into what computing looks like in the workplace. At the same time, it is useful to have context-agnostic cues, indicating the importance of practicing these skills in multiple contexts and encouraging reflection each time to reduce the tendency for skills to be seen as very context-specific (Smith & Vela, 2001). This might be done through project-based and case-based experiences designed to simulate engagement in different contexts (e.g., involving banking vs. healthcare contexts, networking vs. software development vs. security, etc.)

5.4 Dispositions

Dispositions are the attitudes, values, or beliefs that impact a person's actions and behavior (Popham, 2017). They influence people's ability to determine when and how to use their skills and knowledge, and motivate them to follow through (Frezza & Adams, 2020; Perkins et al., 1993; Sabin et al., 2018). For example, a person with appropriate skills and knowledge to perform a task may not perform satisfactorily if they lack suitable dispositions (National Research Council, 2012; Perkins et al., 1993; Resnick & Klopfer, 1989). Therefore, dispositions are crucial to decision-making and dealing with typical struggles in both learning and performing computing, professional, and managerial skills. For example, adaptability is required to deal with the ill-structured, complex problems typically seen in large software development projects. Without this disposition, individuals might either avoid responding to new or contradictory information or be unable to use their technical or professional skills in new ways in order to create innovative solutions.

Although most valuable dispositions, such as those we identified in this study, are not new, as society and the industry changes, some dispositions are newly recognized

as important. For example, a proposed change to ABET for 2024–2025 evaluations (ABET, 2023) would update Student Outcome to: "Recognize professional responsibilities and make informed judgments in computing practice, ***taking into account legal, ethical, diversity, equity, inclusion, and accessibility principles consistent with the mission of the institution***" (bolded words indicate the new verbiage).

Dispositions are increasingly discussed in computing education research. Although most literature that refers to dispositions tends to mix them together with professional skills, use the terms such as 'soft skills,' 'personal traits,' or 'emotional abilities' (Nankivell et al., 2010; Nwokeji et al., 2019). Some view dispositions as fixed attributes of a static personality that cannot be taught, resulting in companies hiring people who already fit the company's needs and a lack of desire to provide professional development activities around dispositions (Lundberg et al., 2018). However, research shows that dispositions *are* teachable and can change through life and work experiences (Frezza & Adams, 2020; National Research Council, 2012; Raj et al., 2021; Sabin et al., 2018). This indicates that they can and should be developed within higher education.

However, teaching dispositions may be more complex than teaching knowledge or skills. Dispositions must be "a substantive component" of the program and tie into the development of a student's professional identity (Schussler, 2006). This requires integration across an entire curriculum, including modeling by *all* faculty across all or most courses in the program. Guest speakers, in-depth interaction with case studies, and reflection activities can be spread across the curriculum to help students identify and engage with each disposition.

Some recommendations for developing dispositions include providing a problem environment that fosters the development of these dispositions, providing opportunities for self-exploration and development of personal theories, and generally developing awareness, inclination, and reflective abilities (Schussler, 2006). For example, a best-possible-self reflection activity may help students identify their personal and professional goals and provide motivation for professional identity development (Duan et al., 2022a, 2022b; Duan et al., 2022a, 2022b). Faculty mentors may also help students recognize when they have demonstrated a disposition or could have demonstrated it. As a simple example, a code-and-test cycle requires perseverance, moving away from many students' belief that they should immediately get a "right" answer. Similar situations occur in teamwork or when working with clients – students must be willing to persevere, empathize, and be intellectually open to discover others' beliefs, values, and needs and, in turn, successfully complete a realistic team project. A faculty mentor may point out these opportunities and model ways to respond to them throughout the project experience.

5.5 Implications for Education

A competency-based approach to education would allow competencies such as those identified to be more explicitly included in college curricula. Furthermore, a move away from the traditional lecture-lab-exam instructional model towards experiential learning (as recommended by the ABET IT criteria's curricular requirements (ABET, 2017) would support the development of managerial and professional skills, while experiential learning may be paired with enculturation and reflection

to support the development of dispositions. Managerial skills development can be fostered by encouraging students to take leadership roles in group projects. Students can be prepared for internships by helping them to select opportunities that align with their goals and by guiding them to observe and reflect on organizational practices during their experience. Programs with structured internships or co-op experiences may also help place students and co-design experiences with supervisors to ensure students gain meaningful professional skills and dispositions. Computing professionals and managers can also be involved as special guests, judges for project presentations, or mentors to help students connect what they learn to what they will do in the future. Across the program, including in introductory courses, case studies can give students access to authentic situations to analyze and respond to – even when technical skills and knowledge have not yet been developed, or the opportunity for interacting with others in an extended experience is impractical. Dispositions, in particular, can be developed through all of these activities with the addition of reflection and careful modeling by instructors throughout the program. As this paper demonstrates, mentors and other professionals have much to share, and programs would benefit from their substantive involvement in curricular decisions.

6 Conclusion & Areas for Future Research

This study includes data from ten interviews with managers who had technical backgrounds. We explored the competencies they reported as required to succeed in their current roles, focusing on the required skills and dispositions. Some of the most commonly discussed skills included managerial skills, such as leadership (emphasizing adjusting managerial style to team members' personalities, project management skills, hiring and evaluating candidates, and mentorship. They also discussed professional skills, with all ten emphasizing the importance of communication, *problem-solving*, and life-long learning. Also frequently mentioned were making judgments, building relationships, and collaboration and teamwork. While these skills may be developed within MBA or other graduate degrees, ABET criteria and curricular guidelines support many of these being included in undergraduate curricula. This supports our findings, which include data from participants who have arrived in their managerial roles after completing computing or related (technical) degrees and working in the field for some time (never having had a management-specific degree). Future research might look into whether these skills are sufficiently fostered in both undergraduate and graduate curricula and whether programs can improve the quantity or type of instruction in these areas.

While participants discussed many important managerial and professional skills, they emphasized the importance of dispositions that support the development and use of those skills – aligning with literature on the relationship between dispositions and skills. Some of the most mentioned dispositions include intellectual openness (especially adaptability and flexibility), having a collaborative mindset, being able to self-evaluate and self-regulate, *having a* life-long learning orientation, *and* being conscientious (with a focus on being intrinsically motivated to do this type of work). Although not elaborated on in this paper, participants added that the aforementioned

skills and dispositions were developed *on the job* during their non-managerial career path as it was a requirement of those roles. Thus, it is apparent that computing graduates need to demonstrate these competencies early in their careers and will benefit from developing them during their degree programs. Future research might look at dispositions for computing professionals at different points in their careers, as well as how to best foster the development of dispositions within higher education programs. This would enable continued discussion in the field regarding the importance of developing dispositions during higher education programs for computing professionals and how they might be included in graduate programs.

Career readiness in the computing industry is not limited to entry-level jobs; professionals should have the opportunity to navigate their preferred career path—whether in technical or managerial roles. Findings from this study help us understand the skills and dispositions needed by managers. In addition to the larger study this paper draws from (asking professionals in various roles about the competencies required on the job), a future study might look into what managers and others involved in the hiring process look for when hiring employees, especially new graduates. This, in turn, may be useful in determining what competencies to focus on when evaluating or designing educational programs.

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Declarations

Conflicts of interest/Competing interests On behalf of all authors, the corresponding author states no conflict of interest.

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