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Editors

Exposing the IT Skills Gap: Surveying Employers' Requirements in Four Key Domains

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Abstract

Information Technology (IT) skills gap discourse suggests a mismatch between what students are acquiring in terms of knowledge and skills in their education versus what employers believe are useful skills for doing day to day tasks. This study builds upon previous research (analyzing the skills of college students in IT-related majors) by surveying industry professionals to determine the skills their organization requires and offering suggestions that can benefit the educational institutions and create a better educated workforce. Implications are drawn and a conclusion is presented.

Keywords: IT skills, competencies, cyber security, infrastructure, development, emerging technologies

1. INTRODUCTION

Year after year, the demand for Information Technology (IT) specialists grows. The expected growth rate from 2019 to 2029 is estimated to be 11%. "IT specialist," however, isn't a single job type; it's a broad category. This adds underlying levels of complexity to that projection. The U.S.

Bureau of Labor Statistics (BLS) groups these jobs into the "Computer and Information Technology" category and further splits it into ten sub-categories. Although being different nomenclature from the above grouping, it is in the eliciting of specific job titles from those sub-categories where the complexity emerges (U.S. Bureau of Labor Statistics, 2020).

The BLS uses the nomenclature of Computer Programmer or Software Developer, but that can manifest in industry job postings as "Full Stack Software Engineer" or "Quality Assurance Engineer." A decade or longer ago, this would not have been the case; job postings would have used the simple labels denoted by the BLS. Industry, however, no longer operates using these simple labels. The change in nomenclature points to a change in expectations of the industry. Whereas IT-related jobs previously operated in silos, we see a shift to more collaborative structures. Someone searching for a job used to use the terms "software developer," where the expectation would be that they only need skills relating to software development. If one were to do a job search today, they would find listings for Full Stack Software Engineers that require skills spanning multiple categories, whereas the BLS categorized Computer Programmers, Database Administrators, Software Developers, and Web Developers as four different jobs. To be successful in today's industry, the Full Stack Software Engineer must have all of those skills. This is the case in most areas of IT. The norm is now integrated, broad, and collaborative knowledge as opposed to individual silos.

Dawson & Thomson (2018) furthered this discussion by examining the need for skills outside the technical realm. While their study pertained to the cybersecurity workforce, this can be generalized to the entirety of IT. They found that domain-specific knowledge and social intelligence were key categories of skills that reached beyond the technical. In order to be successful, employees must have such vital traits as being a systemic thinker, being a team player, having technical and social skills, being loyal to the organization, having strong communication skills, and being a continual learner. Others like Huang, Kvasny, Joshi, Trauth, & Mahar (2009) examined the shift in demands of the industry and noted that skills that did not exist previously have been introduced, such as data warehousing.

The entry-level education requirements of the industry are also changing. 70% of IT-related employers specifically require a Bachelor's degree as a minimum (Robin, 2011). The BLS corroborates this finding, listing the entry-level education requirement as a Bachelor's degree or higher for IT jobs in eight of the 10 categories. Recently, attempts to alter these education requirements have been trending. The push is for more focus being given to certifications and work experience than to college degrees (DevMountain, 2021; Dietrich, 2018; Indeed, 2020). As previously explained, the reality is that well-rounded employees that are molded by a college education are still preferred by companies over those employees with just technical skills.

It is difficult for students to make sense of this skill landscape given the complexities and discrepancies. Furthermore, there is no evidence that students' perception of necessary industry skills aligns with the skills actually required by industry. This study serves to build upon a previous study on student perceptions of skills (Slonka, Bromall, Mishra, & Draus, 2021) by analyzing data from industry organizations and comparing it to the student data. Suggestions will be made that can positively affect both the students and the organizations by arriving at a clearer view of the skills gap.

The majority of the research questions answered by this study mirror those of the previous study except that this study's questions ascertain the viewpoint of industry professionals, not students. The full list of research questions is the following:

RQ1: What levels of experience in the Cyber Security domain do employers expect from IT graduates?

RQ2: What levels of experience in the Infrastructure & Operations domain do employers expect from IT graduates?

RQ3: What levels of experience in the Software Development domain do employers expect from IT graduates?

RQ4: What levels of experience in the New & Emerging Technologies domain do employers expect from IT graduates?

RQ5: To what degree do employers expect experience in non-primary hiring domains?

RQ6: To what degree do employer's knowledge expectations differ from student's self-reported knowledge?

The remainder of the paper is organized as the following. The introduction section above is followed by a critical review of the relevant

literature in the field. Literature review is followed by data collection and analysis section. The results are presented. The discussion section draws the implications of our results followed by the conclusion of the study.

2. REVIEW OF LITERATURE

As one of the most dynamic and rapidly changing fields, Information Technology has a large gap between the knowledge and experience required by the employers, and the ones received by the recent graduates in their academic programs. After graduation the students have to be prepared to a rigorous training, and even the experienced IT specialists are often required to update or change their skills (Koh, Lee, Yen, & Havelka, 2004). Many researchers note a gap between the knowledge perceived necessary by the IT faculty and the knowledge searched by the organizations (Aasheim, Li, & Williams, 2009). Taylor-Smith, Berg, Smith, Meharg, Fabian, & Varey (2019) note that this gap is two-fold. First, there is an overall deficit in digitally skilled workers. Second, the current IT employees and recent graduates demonstrate the lack of appropriate skills. Taylor-Smith et al. also mention that the employees currently prefer that the new hires do not require a substantial training and tend to spend less resources on training.

After a decline in IT programs enrollment observed 15 years ago (Abraham, Beath, Bullen, Gallagher, Goles, Kaiser, & Simon, 2006), the faculty faced a daunting task to create a better match between the requirements of the job market and the content of college programs. In addition to the obvious reason of being more successful in the job market, the students whose skills better match the job market have an increased interest in the content of their programs, and there are multiple studies supporting that. For example, Kapoor & McCune (2018) demonstrated that if students make a clear connection between the knowledge they receive and the real-world applications, they become more successful as professionals. One possibility to improve the students' qualifications before they enter the job market is to give them a professional field training such as internships; however, such training and experiences are still rare (McKenzie & Coldwell-Nielson, 2018).

In this paper we divide the IT skills into four very general categories: Infrastructure & Operations, Software Development, Cyber Security, and Emerging Technologies; however, we anticipate that many professionals are required to be proficient in more than one area. In fact, in spite of an existing public opinion that the IT job requirement has become more "narrow" and broad knowledge is no longer needed, many research studies disprove this statement. Hollister, Spears, Mardis, Lee, McClure, & Liebman (2017) interviewed IT recruiters and found out that the recent college graduates are expected to have knowledge in a broader set of disciplines (database management, programming, security, networking, soft skills, etc.), but this knowledge is not expected to be in-depth.

Many researchers came to the conclusion that, in addition to professional skills, the successful job candidates need excellent soft skills. For example, Haney and Lutters (2016) found that the candidates interviewed for the Cyber Security jobs were expected to possess the innovative skills and the skills to address social and organizational issues, in addition to their professional qualifications. In their study, Dawson & Thompson (2018) concluded that the expectations from a successful candidate are to be a systemic thinker, a team player, have strong communication skills and prepare for continuous learning. With a variety of different skill requirements for the Cyber Security professionals, the standards for the corresponding programs are also set at a very high level. Faculty, courses and the supporting infrastructure such as labs and equipment are listed as the most essential parts of the education process (Dampier, 2015). According to Purdue Global (2018), the Cyber Security graduates must possess the knowledge across six disciplines: Network Security, Digital Forensics, Cybersecurity Policies, Cybersecurity Ethics and Law and Information Systems Security. Although Cyber Security remains an area of IT with a great demand in workforce, it is not the only one on the jobs list. According to Hollister et al. (2017), Infrastructure/Architecture and Operation Support are among the most desirable skill areas, while the CompTIA report of 2021 includes a list of emerging technologies that are in great demand, such as Machine Learning and Artificial Intelligence, Data Analytics and Big Data, and Cloud Technologies (Madden, 2021).

3. METHODS AND RESULTS

Data Collection

An online survey was developed to ascertain hiring professionals' within the IT field self-defined expectations for new hires on their level of knowledge in four domains in the IT field. In addition to the demographic questions, the survey instrument asked the participant to

indicate the level of expertise required for positions in each of the sub-domains, which resulted in 44 questions. These questions elicited the needed experience on a 5-point Likert scale (1=No experience is needed in this area, 2=Basic experience: the applicant should understand the concept, 3=Some experience, 4=Substantial experience: the applicant should be ready to work on a team, 5=Highest level of experience: the applicant should be ready to work alone). Participants were also asked in which of the four domains they *primarily* hire employees and in which of the four domains they ever hire employees (allowing more than one selection).

84 subjects from Western PA IT associations completed the survey. The data from the subject pool showed subjects with many years of experience and a high-level job position. Of those, 37 reported their current job title. 15 were at the C level (CEO/CIO/CTO, president…), 10 at the manager level, and 12 reported being at the Senior level of their role in the organization. Of those reporting their years of experience (N=48), 56% had greater than 15 years with only 8 percent having less than 5 years' experience. On the education side, 65% reported having a bachelor's degree and 30% having earned a master's degree. Only one subject reported having earned a doctorate.

The subjects selected from a list of four areas (Cyber security, Infrastructure & Operations, Development, or New Technologies) as their primary hiring area. As could be expected none of the subjects reported hiring in the "New technologies" area. The majority (62%) reported Cyber Security as their main hiring areas with Infrastructure and operations (25%) and Development (13%) making up the rest. When asked which of the four domains are they actually hiring in the result were Cyber Security (43%), Infrastructure and Operations (26%) Development (17%) and New and Emerging Technologies (21%).

Results

RQ1: What levels of experience in the Cyber Security domain do employers expect from IT graduates?

The overall results for the Cyber Security domain are shown in Appendix A Table 1. Mean values in all domains were at the 'Some' level except for "Security Architecture and Engineering" with a mean (3.85) in the Substantial range. Only one domain had any subjects select at the "None" level. which was in Security Operations and only one domain did not have any ranking at "Highest" which was Asset Security.

The results are consistent with the expectations from fresh hires in the field of cyber security. New graduates are mostly employed in architecture implementation jobs, such as configuration and management of policies, devices, development issues, and risk management.

RQ2: What levels of experience in the Infrastructure & Operations domain do employers expect from IT graduates?

As can be seen in Appendix A Table 2, the employers' highest mean score (3.44) on "Cloud Administration and Support" joined all of the other skills in the "Some Experience" range. Cloud administration and support is quite prevalent and graduates are expected to have working knowledge in AWS or Azure environments to successfully transition in - ground realities of organizational IT functions.

RQ3: What levels of experience in the Software Development domain do employers expect from IT graduates?

All of the skills in this domain were rated in the "Some" level of experience with "Programming Logic" having the highest mean at 3.42 and "Abstraction" (2.81) having the lowest mean rating. All of the results are shown in Appendix A Table 3. Employers understand the changing needs of programming languages and its ability to adapt to newer technologies at a fast pace. It is pertinent that graduates have a solid understanding of topics that constitute fundamentals of programming, such as programming logic, configuring the environment, and testing and debugging. These skills allow graduates to adapt swiftly to newer ways of doing things.

RQ4: What levels of experience in the New & Emerging Technologies domain do employers expect from IT graduates?

All of the sub-domains were ranked at the "Some" level, but interestingly, the "Cloud Computing and Cloud Technologies" topic had nobody select the "None" option. This may signify that Cloud Computing is no longer considered a new and emerging technology. Cloud computing is easily a more prevalent way of providing IT services within and outside the organization. All of the results are shown in Appendix A Table 4.

RQ5: To what degree do employers expect experience in non-primary hiring domains?

Appendix A Table 5 shows the means for each of the four domains grouped by the self-reported primary area of hiring for each subject. As can be seen in Appendix A Table 5, there were no subjects who selected New and Emerging Technologies as their primary hiring area. As can be expected, the highest rated domain for each area was the corresponding area to the subject's hiring domain. It still should be noted that the means in all areas, both primary and non-primary, were all within the same "Some" level of experience. "New and Emerging Technologies" is not clearly defined and refers to all other domains that are not listed as a primary domain. This lack of clarity about the domain results in every respondent interpreting his or her own meaning of the domain. It is not surprising that emerging technologies was not high on the priority list of employers; organizations hire graduates to perform well-defined established tasks.

RQ6: To what degree do employer's knowledge expectations differ from student's self-reported knowledge?

To calculate the difference between the employer expectations and students' self-reported skill levels, the mean of the students was subtracted from the mean of the employers. Appendix A Table 6 shows the sub-domains with differences higher than 1 and Appendix A Table 7 shows sub-domains with differences lower than 1.

The two lowest differences lay in the Infrastructure and Operations Domain: "Application Installing, Configuration and Deployment" and "Desktop Support" and could be called equal.

Appendix A Tables 6 and 7 combined show means across all domains for both students and employers. For the employers, all but two are at the "Some" level of experience. Security Architecture and Engineering had the highest mean (3.85), which is at the "Substantial" level of expected experience. Crypto Currency had the lowest overall Mean (2.46), which was the only one at the "Basic" level. Again, it should be noted the high mean (3.27) for the Cloud Computing and Cloud Technologies ranked at position 7 on the list. It probably should not still be listed as a new and emerging technology.

As can be seen in Table 1, all four domains are present in both tables. Only the New and Emerging Technologies sub-domain shows any real difference in distribution between the higher differences and lower differences tables. This clearly shows that the employers are expecting a higher level of knowledge in these technologies than the students are planning to obtain. IT skills and knowledge are robust in nature and students need to understand that to succeed in this field it requires continuous education and learning.

Domain	Difference > 1		Difference < 1	
	N	%	N	%
Security	4	17%	3	17%
Inf/Op	6	26%	7	39%
Develop	5	22%	4	22%
New	8	35%	3	17%

Table 1: Distribution of Domains

Further analysis between the results of this study (employer perceptions) and the results of the antecedent study (student perceptions) point toward the same conclusion. If the differences presented in Appendix A Table 6 are sorted by the student score one will find that the measure of the student score correlates with the severity of the difference, shown in Table 2.

Domain: Sub-Domain	+/-
Security: Security Architecture and Engineering	-2.04
Inf/Op: Cloud Administration and Support	-1.54
Develop: Container Application	-1.53
Security: Software Development Security	-1.46
Inf/Op: SLA: SL Objective and SLI	-1.44
New: Enterprise/Intelligent Automation	-1.39
New: Robotics Process Automation	-1.38
Develop: Version Control/Deploy/Config/Environment	-1.37
New: Machine Learning and AI/Analytics	-1.31
New: Edge Computing	-1.31

Table 2: Gaps Greater than 1.30

4. DISCUSSION

The IT skills gap suggests a disconnect with what employers want from a graduate and what students are learning in academic institutions. Our study implies that employers expect a certain level of proficiency in IT areas from its hires including new and emerging technologies. The employers are looking for knowledge in current IT domains and competency in fundamental concepts that allow graduates to constantly learn new technologies, adapt, and flourish.

As shown in Table 2, the major gaps are due to the student views being out of line with what is expected by employers. One may infer these gaps are as much about what is *not* being taught in schools as opposed to *how* it is being taught, or even about the amount of schooling the students have obtained. It is important for academia and industry to collaborate closely and for these partnerships to provide opportunities to train the "job ready" graduates in a way that is beneficial to students and employers. The IT industry needs comprehensive academic, technical, and professional competencies and knowledge, skills, and abilities (KSAs) that may not be adequately addressed by traditional college classroom activities. Collaborations and partnerships between information technology (IT) education providers, programs, and industry organizations to improve education and serve the needs of the industry are important (Wang et al, 2020).

This study has implications for practitioners. The study provides a repertoire of topics, skills, and knowledge areas that are typically taught at the university level to IT graduates. Employers can look at the spectrum of content area and identify ways to use the training provided to students for their own needs. This allows organizations to fully utilize the knowledge and competency of hires in a systematic way. This study provides insights into what industry demands of fresh college graduates and university administrators need to gauge the expectations of future employers and adapt in a realistic manner. Additionally, as more and more companies offer on-the-job training or apprenticeship programs (Dishman, 2017; O'Donnell, 2021) it will be important for employers and academic agencies to work closely for mutual benefits and to ensure that this synergistic cohabitation will have long-term implications for all involved parties.

This study has implications for research as well. The first implication is that this study identifies an urgent need to develop collaborative mechanisms for the exchange of information between academia and industry in a meaningful way. Second, more studies are required to refine the expectations of employers in each IT domain such that a more clear and precise understanding of knowledge, skills, and competency is developed. This clarity will allow embedding all the topics in a holistic way.

Although the response rate and participant pool's narrow geographical location could be seen as a limitation, as statistical studies benefit from large response rates, this study does not find those factors limiting. The geographic area from which the participants were pooled represent a microcosm of the nation's technical workforce, with companies ranging from small businesses with less than 10 employees to large corporations, such as Amazon and Google. Additionally, the self-reporting bias plays a role in all research such as this. Because this is such a critical topic in academia and industry, future research should be undertaken to expand the scope.

5. CONCLUSION

This study surveyed IT employers about their expected level of expertise from recent graduates from information systems/technology programs. They survey was based on four specific IT domains: cyber security, infrastructure and operations, software and development, and new and emerging technologies. The results indicated that employers expect proficiency in fundamental topics such as programming logic and debugging and a basic understanding of advanced topics. However, the employers also showed a high preference for skills and competency in the new and emerging technology domain. The results were explained and implications were drawn; the main implication being more collaborative partnership with academia and industry for mutual benefits.

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Appendix A

	Level of Experience %					
Sub-Domains	**None**	**Basic**	**Some**	**Substantial**	**Highest**	**Mean**
Security Architecture and Engineering		20.8	14.6	50	14.6	3.85
Communications and Network Security		16.7	35.4	41.7	6.3	3.38
Software Development Security		25	22.9	43.8	8.3	3.35
Security and risk management		18.8	39.6	39.6	2.1	3.25
Security Assessment and Testing		25	39.6	29.2	6.3	3.17
Security Operations	2.1	33.3	25	35.4	4.2	3.06
Identity and Access Management		29.2	39.6	29.2	2.1	3.04
Asset Security		33.3	47.9	18.8		2.85

Table 1: Cyber Security

	Level of Experience %					
Sub-Domains	**None**	**Basic**	**Some**	**Substantial**	**Highest**	**Mean**
Cloud Administration and Support	2.1	16.7	29.2	39.6	12.5	3.44
Production Environment Support		20.8	37.5	35.4	6.3	3.27
Incident Management	2.1	22.9	33.3	31.3	10.4	3.25
Automation – Scripting		25	35.4	29.2	10.4	3.25
Operating Systems	4.2	18.8	35.4	33.3	8.3	3.23
Networking		16.7	47.9	33.3	2.1	3.21
Server Management		25	43.8	22.9	8.3	3.15
Monitoring, Alerting, Notification	2.1	31.3	33.3	22.9	10.4	3.08
App Installing, Config and Deployment	6.3	29.2	31.3	22.9	10.4	3.02
SLA: SL Objective and SLI		33.3	39.6	22.9	4.2	2.98
Testing Environment Support	4.2	25	47.9	14.6	8.3	2.98
Storage	4.2	31.3	41.7	16.7	6.3	2.9
Desktop Support	12.5	31.3	35.4	12.5	8.3	2.73

Table 2: Infrastructure & Operations

	Level of Experience %					
Sub-Domains	**None**	**Basic**	**Some**	**Substantial**	**Highest**	**Mean**
Programming Logic	2.1	14.6	35.4	35.4	12.5	3.42
Version Control/Deployment/Configure /Environment	4.2	14.6	37.6	39.6	4.2	3.25
Testing and Debugging	4.2	12.5	50	25	8.3	3.21
Data Modeling	4.2	16.7	35.4	43.8		3.19
Database administration, management and development	2.1	20.8	39.6	35.4	2.1	3.15
Container Application	4.2	16.7	47.9	25	6.3	3.12
Event Handling/Interrupts	4.2	25	43.8	25	2.1	2.96
User Interface Design/HCI	12.5	20.8	31.3	31.3	4.2	2.94
Abstraction	6.3	33.3	35.4	22.9	2.1	2.81

Table 3: Development

	Level of Experience %					
Sub-Domains	**None**	**Basic**	**Some**	**Substantial**	**Highest**	**Mean**
Cloud Computing and Cloud Tech		16.7	45.8	31.3	6.3	3.27
Data Science	4.2	25	33.3	31.3	6.3	3.1
Machine Learning and AI/Analytics	8.3	20.8	37.5	25	8.3	3.04
Enterprise Automation/Intelligent Automation	4.2	33.3	27.1	31.3	4.2	2.98
Internet of Things	6.3	27.1	35.4	29.2	2.1	2.94
Edge Computing	4.2	33.3	35.4	25	2.1	2.88
Robotics Process Automation	16.7	22.9	29.2	25	6.3	2.81
Block Chain	12.5	29.2	31.3	22.9	4.2	2.77
Quantum Computing	25	27.1	16.7	22.9	8.3	2.62
Virtual Reality and Augmented Reality	23.4	29.8	25.5	17	4.3	2.49
Crypto Currency	27.1	25	25	20.8	2.1	2.46

Table 4: New & Emerging Technologies

Primary Area	**N**	**Means in the Domains**			
		CS	**I/O**	**Dev**	**New**
Cyber Security	29	3.15	2.95	3.03	2.88
Infrastructure and Operations	12	3.69	3.71	3.5	3.03
Development	6	2.66	2.83	3.1	2.87
New and Emerging Technologies	0				
Overall	47	3.23	3.13	3.13	2.87

Table 5: Primary Domain v Means in each Domain

Sub-Domains	**Domain**	**Employers**	**Students**	**Difference**
Security Architecture and Engineering	Security	3.85	1.81	2.04
Cloud Administration and Support	Inf/Op	3.44	1.9	1.54
Container Application	Develop	3.12	1.59	1.53
Software Development Security	Security	3.35	1.89	1.46
SLA: SL Objective and SLI	Inf/Op	2.98	1.54	1.44
Enterprise/Intelligent Automation	New	2.98	1.59	1.39
Robotics Process Automation	New	2.81	1.43	1.38
Version Control/Deploy/Config/Environment	Develop	3.25	1.88	1.37
Machine Learning and AI/Analytics	New	3.04	1.73	1.31
Edge Computing	New	2.88	1.57	1.31
Data Modeling	Develop	3.19	1.91	1.28
Automation - Scripting	Inf/Op	3.25	1.98	1.27
Production Environment Support	Inf/Op	3.27	2.01	1.26
Block Chain	New	2.77	1.54	1.23
Abstraction	Develop	2.81	1.6	1.21
Quantum Computing	New	2.62	1.41	1.21
Cloud Computing and Cloud Technologies	New	3.27	2.09	1.18
Incident Management	Inf/Op	3.25	2.08	1.17
Event Handling/Interrupts	Develop	2.96	1.79	1.17
Data Science	New	3.1	1.99	1.11
Security Assessment and Testing	Security	3.17	2.13	1.04
Identity and Access Management	Security	3.04	2.03	1.01
Testing Environment Support	Inf/Op	2.98	1.97	1.01

Table 6: Sub-Domain Differences Greater Than 1

Sub-Domains	Domain	Employers	Students	Difference
User Interface Design/HCI	Develop	2.94	1.97	0.97
Server Management	Inf/Op	3.15	2.2	0.95
Communications and Network Security	Security	3.38	2.44	0.94
Programming Logic	Develop	3.42	2.51	0.91
Security Operations	Security	3.06	2.17	0.89
Security and risk management	Security	3.25	2.37	0.88
Database Admin, Management, & Dev	Develop	3.15	2.28	0.87
Asset Security	Security	2.85	1.98	0.87
Monitoring, Alerting, Notification	Inf/Op	3.08	2.37	0.71
Testing and Debugging	Develop	3.21	2.51	0.7
Networking	Inf/Op	3.21	2.72	0.49
Operating Systems	Inf/Op	3.23	2.88	0.35
Internet of Things	New	2.94	2.59	0.35
Storage	Inf/Op	2.9	2.56	0.34
Virtual Reality and Augmented Reality	New	2.49	2.26	0.23
Crypto Currency	New	2.46	2.25	0.21
App Installing, Config, and Deployment	Inf/Op	3.02	3.01	0.01
Desktop Support	Inf/Op	2.73	2.72	0.01

Table 7: Sub-Domain Differences Less Than 1