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Assessing alignment between information technology educational opportunities, professional requirements, and industry demands

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Abstract Information technology (IT) and computing are growing fields, offering far more job opportunities than applicants. Yet, little data are available to indicate how course content, employer needs, and additional learning opportunities work together the prepare graduates to enter the IT workforce. To understand the extent to which learners were prepared to for these highly technical careers, we used text analysis to examine the extent to which course syllabi, job postings, internship postings, and industry certifications from information technology preparation programs at state college and two universities commonly reflected national IT curriculum knowledge areas. Integrated data suggested that while the two-year and four-year programs imparted key technical skills, to qualify employers sought applied, or "soft," skills such as critical thinking, problem solving, teamwork, and written and verbal communication. These soft skills were more difficult to detect as learning outcomes, but the determination of the extent to which the examined programs foster these skills presents a fertile area for subsequent research.

Keywords Computing education · Information technology · Curricula · Internships · Industry certifications

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The Florida Commission on Higher Education Access and Educational Attainment's's (2013) *Aligning Workforce and Higher Education for Florida's Future* report identified critical gaps between Bachelor's degree graduates and future workforce needs in the state of Florida. The authors of the gap analysis identified computing and information technology (IT) occupations as a critical area and specifically recommended that state universities and colleges focus preparing graduates to take on roles as computer network architects, computer systems analysts, computer programmers, applications software developers, systems software developers, and graphic designers. The report authors projected an under-supply of more than 2000 qualified graduates in these six areas.

Florida's IT industry cluster began to develop in support of the nation's space program and was further enhanced with the introduction of the IBM's Personal Computer at their labs in Boca Raton in 1981. From these early efforts, Florida's IT industry has matured into such diverse areas as digital media; modeling, simulation and training; photonics/optics; and mobile technologies. The IT industry cluster is defined as a combination of 51 different industry subsectors from both manufacturing (28) and nonmanufacturing (23). Florida's IT employers and employees are growing steadily and, although employment remains centered in the more populous southern portions of the state, North Florida's strong educational and research infrastructure have made IT a regional strength (Florida Department of Economic Opportunity [DEO] 2016; Forbes 2016).

To explore solutions to this booming employment sector and looming skill shortage, we examined the curriculum, internship opportunities, and industry certification preparation at two universities and a state college in light of professional requirements expressed in national computing standards and job postings. The purpose of this research was not only to assess to extent to which two and four-year computing and information technology programs were preparing students for high need technical jobs but also to provide program administrators with clear directions for strengthening career pathways. Because pathways require the alignment of multiple activities and organizations, strong knowledge of the systems' articulation is essential for school-to-career (Klein et al. 2015; National Association of State Directors of Career Technical Education Consortium [NASDCTEc] 2011), this multi-method research was framed by an overarching question of the extent to which were graduates prepared for IT careers through three questions:

RQ1. To what extent do technology curricula reflect IT professional requirements?
RQ2. To what extent do internship descriptions reflect IT professional requirements?
RQ3. To what extent do IT industry certifications reflect IT curricula?

We integrated data collected for each research question to assess congruence between and establish areas for further research. In this paper, we present the research foundation underlying these questions; the methods used to explore the research questions; summaries of each phase of the research findings; and conclusions in light of the questions posed here. We conclude with possible directions for future research.

1 Literature review

The link between persistence in higher education STEM programs ad STEM technical career has been studied widely. The pace of technological change demands that

students be educated with an ideal IT curriculum that is flexible enough to adapt to a dynamic IT environment and is provided by educators who remain adept at innovative technology advances. This fleet approach requires that stakeholders remain vigilant to the needs of educators, learners, communities, and employers (Brewer et al. 2006).

Employment of computer and IT occupations is projected to grow faster than the average for all occupations (U.S. Department of Labor Bureau of Labor Statistics 2015), which predicates an impending IT workforce shortage. Ideally, computing and IT curricula should be driven solely by the academic needs of students, informed by industry demands, and compliant with international best practice (Hurst et al. 2001). However, computing programs currently often do not attract an adequate supply of students due to perceptions that traditional coursework is insufficient to enable graduates to cope with the practical challenges in current technologies adoption, to acquire strong communication skills and business aptitude to foster problem solving skills, and to find the relevance of program contents to specific occupations (Salzman et al. 2013). Computing curriculum changes are often driven by the need for programs to remain financially viable and in light of fluctuating enrollment (Tan and Venables 2008); concerns about external forces can lead programs to impose curricula that drift away from employer needs and career readiness.

Therefore, effective computing curricula will strongly center industry needs and current recent technological and disciplinary developments (Finkelstein and Hafner 2002; Liu 2007). Curriculum review and revision ensure that an educational program remains relevant and attractive to potential students. For computing and information technology learners, researchers have emphasized the benefit of having a standardized Body of Knowledge (BOK) as a reference point in program design and assessment; curriculum models that define a discipline's BOK—such as the model developed by the Association for Computing Machinery (ACM) and the Institute of Electrical and Electronics Engineers (IEEE). One indicator of a program's success is the employability of its graduates (Khan 2011; Woodward et al. 2013). Because of the rapidly changing technology industry, educational programs must undergo frequent evaluation in order to prepare graduates to enter this dynamic industry, and previous research also highlights that this curriculum evaluation must be informed by industry expertise (Hwang and Soe 2010).

1.1 Computing, information technology, and information systems curricula

ACM first published a set of curriculum models for the computing fields in 1965 (Pasha and Pasha 2012). In an effort to publish current curriculum guidelines for future generations of computing professionals, every 10 years, ACM/IEEE jointly revise their undergraduate computing curriculum framework. Beginning in 2001, this framework was fragmented into 5 CS, Computer Engineering (CE), Information Systems (IS), IT, and Software Engineering (SE) (ACM/IEEE 2015).

Computer science and computer engineering Keeping CS curricula current is challenging. Not only is computing increasingly integrated into other disciplines, but also the CS workforce is expected to have a blend of technical expertise, soft skills (e.g.,

teamwork, verbal and written communication, time management, problem solving, and flexibility), and personal attributes (e.g., risk tolerance, collegiality, patience, appreciation for diversity). A blend of these relevant skills, abilities, and dispositions are important successful professional practice in a variety of career paths. CS2013, the most current version of the ACM/IEEE curriculum, is an effort to promote and provide examples of this blend. The most recent version of the curriculum, CS2013, reflects societal trends such as the increasingly web-based nature of computing and information security and sets levels of mastery for each standard (Roach and Sahami 2015).

Computer engineering (CE) is defined as "the discipline that embodies the science and technology of design, construction, implementation, and maintenance of software and hardware components of modern computing systems and computer-controlled equipment" (ACM/IEEE 2004, p. 4). CE has traditionally been viewed as a combination of CS and electrical engineering. It has evolved over the past three decades as a separate, although intimately related, discipline. CE is grounded in the theories and principles of computing, mathematics, science, and engineering, and it applies these theories and principles to solve technical problems through the design of computing hardware, software, networks, and processes (ACM/IEEE 2004). The ACM/IEEE CE curriculum guidelines were last revised in 2004, and they aim to offer direction and curriculum coherence in what is a generally expansive and varied field (Ricks et al. 2008).

Information systems Unlike CS and CE programs, IS programs exist at the intersection of business and technology, and graduates are expected to navigate between the two fields (Henson and Kamal 2010; Plice and Reinig 2007). Often, hiring officer have difficulty distinguishing between IS graduates and graduates from other computing disciplines such as CS or IT, believing that a graduate of any computing program is capable of performing the same functions. However IS programs deliver unique business-oriented competencies that other programs may not provide (Rosenthal 2010).

IS graduates can expect to work in a broad array of fields such as government, business, and healthcare (Topi et al. 2010).Because careers in IS fields require that employees interact with customers who may lack technical knowledge but meet their needs using technical solutions, much emphasis in an IS curriculum is placed on non-technical skills such as business and communication skills and technical skills (Alshare et al. 2011). Business skills may include competencies such as knowledge of marketing or finance and management skills (Martz and Cata 2008) and technical skills may include competencies such as developing a foundational knowledge of IT systems (Alshare et al. 2011).

Although communication and interpersonal skills are emphasized in the IS curriculum, IS graduates and employees are still expected to maintain technical knowledge. Instead of focusing on a specific area of technical expertise such as databases as one may do in another technical program, IS professionals are expected to have a foundational understanding of how IT functions as a system and also be able to demonstrate a holistic range of technical competencies (Sauls and Gudigantala 2013). IS professionals are required to exhibit a diverse skill set (Henson and Kamal 2010) even for entry-level positions. According to Plice and Reinig (2007) IS is "technology-enabled business development" (p. 24). Therefore, highly sought-after expertise includes technology skills, communication and interpersonal skills, the ability to think analytically and critically, and fundamental business competencies.

These unique program features are reflected in the ACM/Association for Information Systems (AIS) 2010 Model Curriculum Guidelines. Since the 1970s, the ACM/AIS have developed curriculum guidelines for IS programs since the 1970s that seek to reflect the evolutions in technology and industry needs (Topi et al. 2010). The ACM/AIS guidelines specify that IS professionals must work closely with IT professionals and must demonstrate "sound technical knowledge of computers, communications, and software" (Topi et al. 2010, p. 12) as well as a knowledge of organizational functions and other business skills. Furthermore, the ACM/AIS 2010 curriculum guidelines specify several high-level IS capabilities that students may be exposed to in an IS program. These include: "improving organizational processes, exploiting opportunities created by technology innovations, understanding and addressing information requirements, designing and managing enterprise architecture, identifying and evaluating solution and sourcing alternatives, securing data and infrastructure, and understanding, managing and controlling IT risks" (Topi et al. 2010, pp. 16–18).

Although the nature of the IS discipline is different from that of other computer-related disciplines, research related to IS programs is similar to the research conducted to study other computing disciplines such as IT or CS. Previous researchers like Mills et al. (2012) have examined IS program content by comparing existing IS curricula to the ACM/AIS curriculum guidelines. Previous research has relied on employer input through surveys or interviews to determine skill requirements for graduates seeking employment in the field (Plice and Reinig 2007).

1.2 Industry certifications

In addition to allowing recipients to obtain skills in a self-directed, self-selected "stacked" or "latticed" format, industry certifications offer a way for academic programs to remain current with industry demands (Fedak et al. 2011). The growing demand for IT knowledge and skills from industry and the government is motivating academic institutions to produce graduates who have the necessary skills to be productive as they join the workforce (Al Rawi et al. 2005). Often in the hiring process, individuals who have acquired certain credentials are determined to possess a baseline of skills associated with that credential (Hunsinger and Smith 2009; Hunsinger et al. 2011; Wierschem et al. 2010),

The IT certifications were vendor-specific and vendor-neutral. Companies such as Cisco offer certifications specifically related to their products in response to the need for qualified and knowledgeable employees who know their products. Trade organizations such as CompTIA provide certifications that are not tied to a particular product but provide fundamental knowledge of a particular area of computing such as foundations of computer hardware, software, and basic networking (Ejiaku et al. 2010). Vendors such as Oracle and Microsoft offer training courses for their certifications, and some community colleges design their program to concentrate on a specific field (Zeng 2004).

Certifications also may function as a signal to employers that a potential employee has the ability to remain current with a certain technology and is committed to continuing professional and skill development, as many certifications require eventual recertification; research also indicates that employers perceive certification-holders as individuals who will require reduced training time (Wierschem et al. 2010). Previous

research suggests that students pursuing IT disciplines perceive that certifications enhance their employability and set them apart from other candidates because employers view certifications as a substitute for real-world experience (Hunsinger and Smith 2009; McGill and Dixon 2005).

The role of IT certifications in hiring processes is unclear; few job posts mention any required certifications, and employers may still prefer experience combined with formal education (Anderson et al. 2005; Benham 2006; Rob and Roy 2013). In two related studies (Cegielski and Hall 2009; Hunsinger and Smith 2009), researchers found that human resources (HR) professionals valued IT certifications more than IT professionals in charge of hiring, as IT professionals do not necessarily find that certification attainment directly relates to specific job competencies. Hua (2013) argued that incorporating vendor materials in curricula risked a loss of academic freedom for faculty if the learning outcomes of the course are altered to correspond with certification outcomes.

The synthesis of certification outcomes and course learning outcomes has been a focus for academic institutions seeking to integrate IT certifications into their existing computing curricula, particularly at the university level. Previous work has been done to map certification learning objectives and exam contents to IT course topics and learning objectives in order to determine into which course the IT certification would best fit (Al Rawi et al., 2005, 2006; Nelson and Rice 2001; Poteat 2006).

1.3 Internships

Employers have expressed concerns with the job readiness of graduates in IT-related disciplines, noting that students or graduates who are highly skilled in technical competencies often lack valuable general workplace competencies or soft skills (Galloway et al. 2014; Venables and Tan 2009). Researchers examined the potential value of internships for undergraduate IT students from the perspectives of students in computing disciplines, IT employers, and postsecondary academic administrators and found all stakeholders viewed non-technical courses, capstone projects, team projects, and internship programs as important links between education and employment (Makasiranondh et al. 2011; Ralevich and Martinovic 2010).

Although internships have been positioned as a means of increasing employability, students who already exhibit desired workplace competencies were more likely to secure internship positions than students who could needed to develop business or soft skills. (Chillas et al. 2015). Because many employers expect interns to be competent workers as opposed to inexperienced students requiring training, some employers have become less unwilling to offer internship opportunities due to potentially high immediate investments in training time, supervision, and lowered productivity (Ralevich and Martinovic 2010).

1.4 Information technology employment

Students aim to culminate their classroom learning, internship experiences, and certifications in well-paid IT jobs. While some students may enter jobs as a result of internship experiences, many IT works locate jobs through postings (Debuse and Lawley 2009; Smith and Ali 2014). Online job search sources are crucial for IT job

seekers because the job postings are more context-rich and more likely to specify desired soft skills and technical competencies (Gallivan et al. 2004).

A seminal study of employers' desired computing skills, Todd et al. (1995) analyzed 20 years of job advertisements in four major newspapers from 1970 to 1990. They found that the ads focused on technical skills, with the frequency of stated technical requirements increasing dramatically over the study period. Galup et al. (2004) analysis of job postings observed a similar technical skills trend and noted that a decade later, software design was already eclipsing a need for programming or hardware knowledge. Lee and Han (2008) analyzed the programmer/analyst skills requirements in Fortune 500 company IS job ads and concluded these positions required candidates to technical, business and programming roles as well as possess skills such as development, software and social skills; by 2008, technical job postings encompassed network architecture, hardware, and problem solving.

Regardless of their emphases, job postings' content may reveal a disconnect between the classroom and the workplace. In a study of new Management and Information systems (MIS) graduates, Downey et al. (2008) compared MIS professionals' skills to skills included in MIS curricula (2008); they located a mismatch between the two sets, an emphasized that closer coordination between employers, faculty, and students would better set realistic workplace expectations and inform curriculum.

2 Methods

We used automated text analysis to describe and quantify data from two universities and a state college in Florida. Data were analyzed in reference to prevailing state and industry standards and triangulated to highlight overlaps and gaps.

2.1 Study participants and data sources

Study participants include two universities located in a strong regional IT industry cluster (Florida Department of Economic Opportunity [DEO] 2016). Profiles were taken from the Carnegie Classification of Institutions of Higher Education (Indiana University Center for Postsecondary Research 2016):

University A is a public doctoral granting institution in the "High Research Activity" Carnegie classification with just over 10,000 students. It is a professional-dominant university with high, primarily residential undergraduate enrollment.

University B is a large public doctoral granting institution in the "Highest Research Activity" Carnegie classification with over 43,000 students. It has a high graduate and undergraduate enrollment in balanced between arts & sciences and professions. The undergraduate population is primarily non-residential.

Data were also provided by a large urban state college with just over 25,000 students. Located in a hub for many IT companies (Kotkin 2013), this state college offers Baccalaureate and Associate's degrees to a primarily nonresidential part time student population. The state college is a major source of transfer students into the computing and IT programs at University A and University B.

2.2 Data collection and analysis

Our data collection and analysis was concentrated in four phases: computing and IT course syllabi from the 2014–2015 academic year and contemporaneous industry certifications, job postings, and internship postings.

Phase I. Syllabi The research team analyzed a total of 245 syllabi, as shown in Table 1.

Course titles for each program are listed in Appendix A. We began the analysis process by identifying academic curriculum standards used by the universities and state colleges. We employed the standards from the Florida Department of Education (FLDoE) for Information Technology and the ACM/IEEE undergraduate curriculum standards Information Technology (IT), Computer Science (CS), and Computer Engineering (CE). We used the standards published by the ACM and the Association for Information Systems (AIS) for the Information Systems (IS) course syllabi (Topi et al. 2010).

Then, we compared state college syllabi to the FLDoE IT curriculum standards framework. Using Python programming language to automate text processing and keyword extraction, we identified learning outcomes in the syllabi. We compared learning outcomes to the ACM/IEEE undergraduate computing curriculum guidelines. For University A's Information Systems (IS) curriculum analysis, we used the ACM/AIS 2010 IS curriculum guidelines. Fig. 1 overviews the syllabus analysis process.

Table 1 Syllabi by school, program, and degree ($N = 245$)

School	Program	Degree	Syllabi (n)
University A	Computer Science (CS)	B.S.	15
	Information Systems (IS)	B.S.	14
	Information Technology (IT)	B.S.	15
Total University A			44
University B	Computer Science (CS)	B.A.	12
		B.S.	17
	Information Technology (IT)	B.S.	26
Total University B			55
University A&B (Combined Program)	Computer Engineering (CE)		21
State College	Computer Information Technology (CIT)	A.S.	31
	Networking Systems Technology (NST)	A.S.	50
	Information Technology Management (ITM)	B.A.S.	24
	Computer Systems Networking & Telecommunications (CSNT)		20
Total State College			125
Grand Total			245

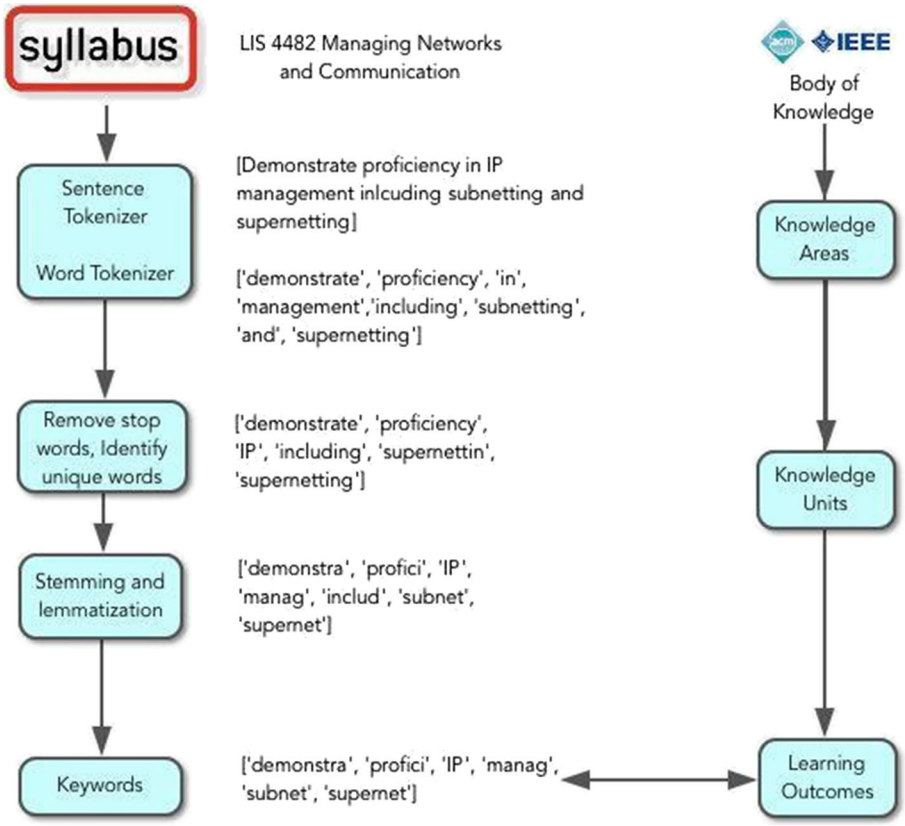

Fig. 1 Syllabus analysis process

Figure 1 illustrates the Python script that we used to extract key words and phrases relating to knowledge areas from the syllabi and the 2008 ACM/IEEE curriculum guidelines. The knowledge areas are:

- Human Computer Interaction (HCI)
- Information Assurance and Security (IAS)
- Information Management (IM)
- Information Technology Fundamentals (ITF)
- Integrative Programming & Technologies (IPT)
- Math and Statistics for IT (MS)
- Networking (NET)
- Platform Technologies (PT)
- Social and Professional Issues (SP)
- System Administration and Maintenance (SA)
- System Integration and Architecture (SIA)
- Web Systems and Technologies (WS)

We compared the two sets of knowledge area words and phrases and calculated levels of similarity. For the state college, we used the *2014–2015 FLDoE Computer*

Information Technology Framework (Florida Department of Education [FLDOE] 2014), which is designed to guide computing and IT programs at state and community colleges. The FLDoE's Computer Information Technology framework is based on the IT framework originated in U.S. Department of Education's National Career Clusters Framework now maintained by Advance CTE (formerly National Association of State Directors of Career Technical Education Consortium (Advance CTE, Advance 2007). In the IT career cluster program, FLDoE lists competencies that the student will ideally be exposed to in the course. The programs are further broken down into courses, for which the FLDoE specifies certain course standards, learning outcomes, or core competencies that a student should achieve upon completion of the course.

Limitations. For the purposes of this analysis, we considered only core courses in the targeted programs; it is possible that additional learning outcomes were covered in elective courses. Additionally, only syllabi were analyzed and certain learning outcomes and knowledge areas may be covered in other aspects of the courses, such as lectures and assignments.

Phase II. Industry certifications In this phase, we compared the learning objectives specified in IT certifications recommended by the two universities to their Bachelor's of Science in Information Technology (BSIT) program course learning outcomes. As Table 2 shows, we analyzed the content of 15 certifications recommended by the participating programs. All certifications were current as of 2014.

All IT certifications featured specific objectives and required mastering certain skills that are not necessarily included in IT curricula (Al Rawi et al. 2005) IT program courses have specific objectives and outcomes that need to be achieved in order to pass the course and fulfill the graduation requirement. In *Information Technology 2008: Curriculum Guidelines for Undergraduate Degree Programs in Information Technology*, ACM/IEEE (2008) noted that "many certifications are specific to a given vendor and are very narrowly focused. They therefore usually do not meet the learning outcomes defined in IEEE Curriculum Guidelines document" (p. 48). Similar to previous research conducted by Al Rawi et al. (2005), this study sought to determine the content overlap between industry certifications and program courses by extracting and comparing the certification objectives to the learning objectives from IT program courses. It examines specific areas of potential certification integration from selected programs of University B and University A.

We used the same text analysis process with the certifications as we used for the syllabi analysis. Once we identified certification objectives, we identified learning objectives from university courses are covered in certifications, suggesting that the certification could be logically integrated into the course. For each certification, we considered all potentially relevant courses in the University B and University A undergraduate IT programs. If all the certification knowledge areas were covered in the course or courses analyzed, we determined that the course(s) and the specific certification were a complete match.

Limitations. Certification outcomes or domains were only compared to learning outcomes listed in course syllabi. Although they are an important aspect of the curriculum, course syllabi cannot fully convey all course content. Some certification objectives not matched with learning outcomes in course syllabi may be conveyed in other areas of course instruction such as textbooks, assignments or lectures.

Table 2 Analyzed certifications by vendor and name ($N = 15$)

Vendor/Association	Certification
Project Management Institute, Inc.	Project Management Institute's Certified Associate in Project Management (CAPM)
CompTIA	Computing Technology Industry Association Basic A+
CompTIA	Computing Technology Industry Association Network+
CompTIA	Computing Technology Industry Association Security+
CompTIA	Computing Technology Industry Association Linux+
W3S	W3Schools Certification: HTML & HTML5
W3S	W3Schools Certification: CSS
Oracle	Oracle MySQL Database Developer
Oracle	Oracle MySQL Database Administration
Information System Security Certification Consortium, Inc., $(ISC)^2$®	Information Systems Security Professional (CISSP)
VMware	VMware Certified Associate – Data Center Virtualization
Cisco	Cisco Certified Network Associate (CCNA)
Cisco	Cisco Certified Network Professional (CCNP)
W3S	W3Schools Certification: PHP: Hypertext Preprocessor
W3S	W3Schools Certification: XML: Extensible Markup Language

Phase III. Job and internship postings We then examined job and internship postings extracted from the University B Career Center and provided by state college. The job posting and internship data are described in Table 3.

Many job and internship postings were common in all the 4 programs. So, after combining these data, a total of 134 unique job postings and 82 unique internship postings were analyzed. All job and internship postings were posted between January 1, 2014 and December 31, 2014.

We employed Leximancer software to analyze the job postings. A powerful software tool designed for analyzing natural language text data, Leximancer allowed us to identify, as Bozkurt and Helm (2013) noted, "concepts [that] are not just keywords

Table 3 Job Posting and internship posting data (January–December 2014)

School	Program	Job Postings (N)	Internships (N)
University B	CE	82	30
	CS	126	73
	IS	33	17
	IT	66	48
State College	All programs	73	–
	(CIT, NST, ITM, CSNT)		
Initial Posting Totals	380	168	
Unique Posting Totals	134	82	

that occur frequently, but words that 'travel together' [i.e., are paired together] throughout the text" (p. 340). Leximancer generated a visual concept map that illustrated terms' relative connectedness by proximity. These relationships allowed us to visualize the main themes in job postings and required skills specified in the job postings.

In addition to the concept map, Leximancer generated a list of the most frequently occurring concepts in the text. We then compared the concepts in the job postings with concepts in the syllabi to assess the extent to which the academic programs were providing students with content that matched the needs of local technology employers. We employed a similar process to analyze the internship postings ($N = 82$) for the same one-year period of time.

3 Results

3.1 Phase I. Syllabi analyses

In this section, we present the results of the comparisons between course learning outcomes and curriculum guidelines. Course titles and credit hours are listed in Appendix A.

University a computer science (CS) In comparing the University A CS course syllabi to the ACM/IEEE CS curriculum guidelines, we observed that four Knowledge Areas were 100% covered: Algorithms & Complexity, Information Management, Networking and Communication, and Operating Systems. Ten Knowledge Areas had partial (i.e., less than 100%) coverage in Computational Science, Discrete Structures, Graphics and Visualization, Human Computer Interaction, Information Assurance & Security, Intelligent Systems, Parallel and Distributed Computing, Social and Professional Practice, Software Engineering, and Systems Fundamentals. Based on the analysis, we determined that there was similarity between the University A CS courses and the ACM/IEEE CS curriculum guidelines.

University a information systems (IS) We found a great deal of similarity between the University A IS course learning outcomes and the core courses outlined in the ACM/AIS curriculum guidelines. Those core courses were Foundations of Information Systems; Data and Information Management; Enterprise Architecture; IS Project Management; IT Infrastructure; Systems Analysis and Design; and IS Strategy, Management and Acquisition.

We determined that 5 out of 7 (71.4%) suggested core courses demonstrated more than 60% learning outcome coverage in University A IS syllabi ($N = 14$), meaning that more than 60% of the suggested learning outcomes in the ACM/AIS curriculum guidelines were included in the course syllabi analyzed. There were no instances of a core course in which learning outcomes were not at least partially covered in the syllabi analyzed. Figure 1 illustrates the percent coverage of learning outcomes in each core course demonstrated by the University A's IS course syllabi.

As Fig. 2 suggests, overall, 90% of the learning outcomes in IS Strategy, Management and Acquisition course were covered in University A IS syllabi. This includes 85.71% of the learning outcomes in Foundations of Information Systems, 76.92% of

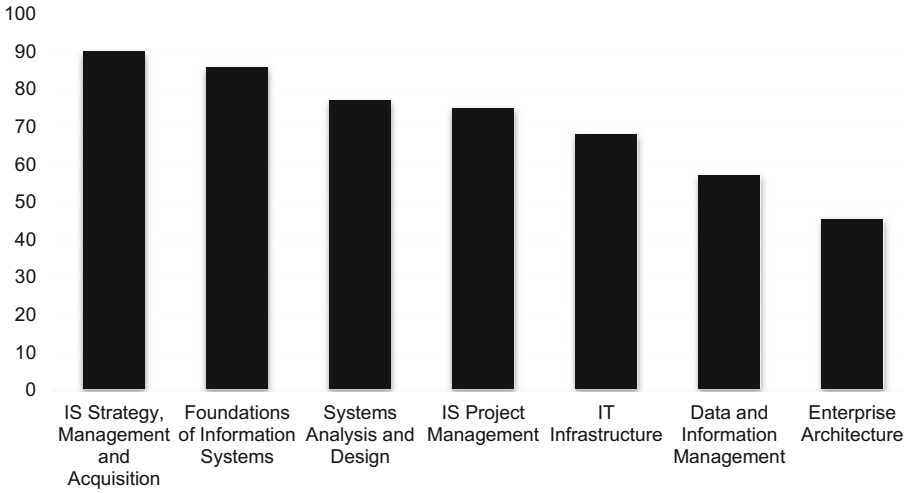

Fig. 2 Percentage of ACM/AIS competencies covered in University A IS Syllabi ($N = 14$)

the learning outcomes in Systems Analysis and Design, 75.00% of the learning outcomes in IS Project Management, 68.00% of the learning outcomes in IT Infrastructure, 57.14% of the learning outcomes in Data and Information Management, and 45.45% of the learning outcomes in Enterprise Architecture courses.

University a information technology (IT) Our analysis demonstrated a strong similarity between the University A IT course learning outcomes and the ACM/IEEE IT curriculum guidelines. We determined that 12 out of 13 (92.3%) of the Knowledge Areas specified in the ACM/IEEE IT curriculum guidelines were more than 60% covered in the University A IT syllabi ($N = 15$). Only the Knowledge Area of Integrative Programming and Technologies covered less than 60% of the related Knowledge Unit.

University B computer science (CS) Our analysis of 12 course syllabi for required courses in the Bachelor's of Arts (BA) in CS and 17 course syllabi for required courses in the Bachelor's of Science (BS) in CS demonstrated strong similarity to the ACM/IEEE curriculum guidelines in 17 out of 18 Knowledge Areas (94%). The Knowledge Areas that demonstrated more than 60% similarity to the ACM/IEEE CS curriculum guidelines are: Algorithms, Architecture and Organization, Discrete Structures, Information Assurance, Information Management, Networking and Communication, Operating Systems, Parallel and Distributed Computing, Programming Languages, Software Development Fundamentals, Software Engineering, Systems Fundamentals, and Social Issues and Professional Practice. Only the Platform-Based Development Knowledge Area was not reflected in the course syllabi learning outcomes.

University B information technology (IT) Based on the syllabus analysis, we determined a strong similarity between learning outcomes and the ACM/IEEE curriculum guidelines in 12 out of 13 (92%) Knowledge Areas. In University B syllabi, we observed the highest level of similarity in the Knowledge Areas of, Information Assurance and Security, Information Management, Information Technology

Fundamentals, Networking, Platform Technologies, Social and Professional Issues, and Web Technologies.

Additionally, we observed similarity between learning outcomes in course syllabi and the curriculum guidelines for the Knowledge Areas of Human Computer Interaction, Integrative Programming and Technologies, Programming Fundamentals, Systems Administration and Maintenance, and Social and Professional Issues. Math and Statistics for IT was the only Knowledge Area not represented in the analyzed University B course syllabi.

University a & B (CE) The syllabi we analyzed contained Knowledge Units from 15 out of 18 (over 80%) ACM/IEEE CE Knowledge Areas. When we compared the learning outcomes extracted from the syllabi to the ACM/IEEE Knowledge Areas in the CE, we observed a large amount of similarity in Computer Architecture and Organization, Circuits and Signals, Digital Logic, Digital Signal Processing, Discrete Structures, Electronics, Embedded Systems, Operating Systems, Probability and Statistics, and Programming Fundamentals. The results of this analysis suggest that the University A/University B CE program strongly reflected ACM/IEEE curriculum guidelines.

State college computer information technology (CIT) and networking systems technology (NST) programs Of the 81 courses analyzed from the Associate of Science (AS) in Computer Information Technology (CIT) and AS in Networking Systems Technology (NST), 69 (85%) courses belonged to the FLDoE Information Technology career cluster, while seven (9%) courses belonged to the business, management & administration career cluster, three (4%) courses were from the finance career cluster and one (1%) course each were from Engineering & Technology Education and Arts AV Technology & Communication career clusters. Table 4 depicts the percent of learning outcome match between state college course learning outcomes and FLDoE frameworks.

As Table 4 suggested, overall, the course outcomes reflected relatively little alignment with the FLDoE frameworks the Networking Services Technology degree courses having the most in common with FLDoE's IT curriculum framework.

3.2 Phase II. Industry certification analysis

From the analysis of 15 IT industry certifications and related University B and University A IT courses, we determined that both universities' courses covered all of the learning objectives for three certifications (Oracle MySQL Database Developer, W3Schools CSS, and W3Schools PHP). University A's courses covered 12 out of 15 certification knowledge areas and exam contents and University B's courses partially covered all learning objectives and exam contents for 13 out of 15 certifications. University A provided no content to help students prepare for the VMWare Certified Associate—Data Center Visualization certification. Present and missing concepts are further detailed in Appendix B.

Table 4 State College and Florida Department of Education IT framework match

Degree name and program	FLDoE Framework Match (%)
Associate's of Science in Computer Information Technology (AS CIT)	
Business Administration	3.2
Computer Information Technology	22.6
Computer Programming and Analysis	38.7
Database Technologies	9.7
Digital Media/Multimedia Technologies	3.2
Financial Services	3.2
Internet Services Technology	9.7
Networking Services Technology	9.7
Associate's of Science in Networking Systems Technology (AS NST)	
Business Administration and Management	4.87
IT Security	4.87
Networking Services Technology	85.3
Computer Engineering Technology	2.43
Computer Information Technology	2.43
Bachelor of Applied Science in Computer Systems Networking and Telecommunications (BAS CNT)	
Business Administration	5
IT Security	5
Networking Services Technology	90
Bachelor of Applied Science In Information Technology Management (BAS ITM)	
Business Administration	20.8
Computer Information Technology	29
Computer Programming and Analysis	8.3
Database Technology	12.5
Financial Services	12.5
Networking Services Technology	16.6

3.3 Phase III. Job posting analysis

The job posting analysis included 134 jobs in the sectors of E-Commerce (8); Education (1); Engineering (7); Financial (9); Government (13); Health Care (2); Insurance (2); Railroad.

(3); Research (1); Retail (2); Telecommunications (1); and Technology (85). Table 5 depicts the summary of the job posting analysis by the 968 mentions of specific ACM/IEEE IT knowledge areas, as well as the number of knowledge area mentions per job overall.

As Table 5 shows, each job included 7.23 mentions of specific knowledge area with the most frequent occurrences in the System Integration and Architecture knowledge area across all sectors at 1.17 mentions per job, followed by Programming

Table 5 Job posting knowledge areas by industry sector ($N = 134$)

ACM/IEEE Knowledge Area	Knowledge Area Mentions by Sector (n jobs)													
	E-Commerce (8)	Education (1)	Engineering (7)	Financial (9)	Government (13)	Health Care (2)	Insurance (2)	Railroad (3)	Research (1)	Retail (2)	Telecomm (1)	Technology (85)	Total (134)	Mention per Job
Human Computer Interaction	9	0	1	2	21	3	0	0	0	2	0	29	67	.50
Information Assurance and Security	0	0	0	0	10	0	0	0	0	0	0	6	16	.12
Information Management	6	1	2	6	20	0	0	4	1	3	1	41	85	.63
Integrative Programming & Technologies	4	0	2	3	0	2	0	3	0	0	0	22	36	.27
Math and Statistics for IT	0	0	0	2	4	0	0	1	0	0	0	0	7	.05
Networking	0	0	0	1	15	0	0	1	0	1	0	0	18	.13
Programming Fundamentals	7	11	0	1	5	0	1	5	0	4	2	56	92	.69
Platform Technologies	0	0	0	1	6	0	1	2	0	3	0	10	23	.17
System Administration and Maintenance	0	0	11	2	26	1	1	6	2	3	1	34	87	.65
System Integration and Architecture	0	4	6	7	18	2	1	4	0	8	2	105	157	1.17
Social and Professional Issues-Business Fundamentals	0	3	4	2	11	0	1	1	0	3	0	39	64	.48
Social and Professional Issues-Communications	0	0	2	3	8	2	1	1	0	2	0	23	42	.31
Social and Professional Issues-Customer Service	0	0	2	1	13	0	0	0	1	1	0	39	57	.43
Social and Professional Issues	2	1	3	2	4	0	0	1	0	2	0	18	33	.25
Social and Professional Issues	0	0	0	1	0	0	0	0	0	0	0	7	8	.06

Table 5 (continued)

ACM/IEEE Knowledge Area	Knowledge Area Mentions by Sector (n jobs)													
	E-Commerce (8)	Education (1)	Engineering (7)	Financial (9)	Government (13)	Health Care (2)	Insurance (2)	Railroad (3)	Research (1)	Retail (2)	Telecomm (1)	Technology (85)	Total (134)	Mention per Job
Social and Professional Issues-Problem Solving	1	0	2	0	8	0	0	4	0	0	0	16	31	.23
Social and Professional Issues	4	1	0	1	4	2	0	0	0	0	0	23	35	.26
Social and Professional Issues	0	1	1	1	5	1	0	2	2	0	0	41	54	.40
Web Systems and Technologies	0	0	1	2	12	6	0	2	1	1	1	30	56	.42
Totals	33	22	37	38	190	19	6	37	7	33	7	539	968	7.23

Fundamentals (.69 per job); System Administration and Maintenance (.65 per job); and Information Management (.63 per job). Note that although Social and Professional Issues are broken down into several concepts, they comprise the largest area of knowledge domains at 2.42 per job. This knowledge domain is difficult to code because Social and Professional Issues are affective and interlinked; for this reason, we recommend interpretation at a higher level of conceptual granularity.

Appendix C details the links between competencies job titles listed in job postings and specific curriculum content from University B; as the results of the Phase I syllabi analysis indicated, the curriculum for University A and University B was very similar. Appendix C demonstrates that, for the most part, the job titles required similar technical competencies and general competencies, just with varying emphases. Knowledge of platform fundamentals and/or platform technologies as well as systems integration and architecture, networking, and/or systems administration were important to all of the job titles. The least common technical competency was computer science, which was only mentioned in relation to the job postings for software developers.

General competencies also cross cut job posting requirements with professional communications, business fundamentals, and teamwork being the most common. Accountability and creative thinking were mentioned only once each.

3.4 Phase III. Internship posting analysis

In this analysis, we found that the internship postings greatly emphasized technical competencies over general competencies. From the 82 unique internship postings, 363 technical competencies were identified but only 114 general competencies were identified, as Table 6 shows.

Web Systems and Technologies was the most frequently identified technical competency. The job postings analysis found the share of this competency was 15.3% while the

Table 6 Technical competencies in internship postings

Technical competency	N (%)
Web Systems and Technologies	103 (28.3)
System Integration & Architecture	58 (14.6)
Information Management	41(11.3)
Systems Administration and Maintenance	38 (10.47)
Human Computer Interaction	29 (7.98)
Programming Fundamentals	22 (6.06)
Platform Technologies	19 (5.23)
Integrative Programming and Technologies	17 (4.7)
Information Assurance and Security	12 (3.3)
Networking	12 (3.3)
Embedded Systems (Computer Engineering)	6 (1.67)
Algorithms (Computer Science)	4 (1.1)
Math and Statistics for IT	2 (0.55)
Total	363 (100)

BSIT curriculum analysis reported it as 12.43%. According to the ACM/IEEE 2008 IT curriculum guidelines that served as the codebook for this analysis, this knowledge area "covers the design, implementation, and testing of web-based applications including related software, databases, interfaces, and digital media. It also covers social, ethical and security issues arising from the Web and social software" (ACM/IEEE 2008). Web System specific technologies like HTML5, CSS, JavaScript, JQuery, PHP, XML, ASP and AJAX were identified from internship postings. Even though technologies like HTML5, CSS, JavaScript, PHP were covered in the curriculum, technologies like ASP, AJAX, JQuery were not part of any BS in IT program. Therefore, the internships included technologies not covered in curriculum. When contrasted to the general competencies derived from the job postings, however, employment seems to require more systems and network knowledge than web systems and technology knowledge.

In addition to technical competencies, the analysis also identified general competencies from the internship postings, which are illustrated in Table 7.

As Table 7 indicated, professional communications was the most frequently identified competency identified in the internships advertised during this period. Specifically, out of 114 general competencies identified from internship postings, the frequency of Professional Communications was 25 (21.9%). As with the general competencies reflected in job postings, professional communications, teamwork, and business fundamentals were important while accountability and creative thinking were less emphasized.

4 Discussion

In an attempt to discern the extent to which North Florida computing education programs were preparing students for careers, we examined course syllabi from a state college, University B, and University A and compared their contents to prevailing curriculum and professional standards; industry certification requirements; and job and internship posting content.

Table 7 General competencies in internship postings

General competency	Frequency (%)
Professional Communications	25 (21.9)
Teamwork	20 (17.54)
Business Fundamentals	18 (15.78)
Problem Solving	13 (11.4)
Self Management	11 (9.64)
Accountability	9 (7.89)
Interpersonal Skills	5 (4.38)
Creative Thinking	4 (3.5)
Flexibility	3 (2.63)
Customer Service	6 (5.26)
Total	114 (100%)

4.1 RQ1. To what extent do technology curricula reflect IT professional requirements?

The large-scale review of syllabi affirmed that by and large, two year and four year programs at state college, University A, and University B imparted the IT and computing skills outlined in state and national frameworks. University A covered over 60% of ACM/IEEE Knowledge Areas University B's syllabi demonstrated over 80% ACM/IEEE Knowledge Areas. Only one state college course shared the majority of its learning outcomes with the FLDoE IT curriculum framework. These results suggest that state college and university programs work best as a continuum, since our analysis also suggests that that state college IT curriculum strongly reflects many non-technical knowledge and skills reflected in high need job areas, as indicated by job postings. State college IT curricula also appear to impart the technical requirements listed in job postings. However, the concepts grouped under business and interpersonal skills, i.e., communication skills and team building skills, were not listed as specific learning objectives in the syllabi.

4.2 RQ2. To what extent do internship descriptions reflect IT professional requirements?

From our internship posting analysis, we concluded that students could expect to gain workplace experience and an exposure to technical and general competencies, which is consistent with previous research. Although much of the literature (e.g., Galloway et al. 2014) emphasized the non-technical competencies (teamwork, communication, and professionalism skills, etc.), this analysis found that the internship postings greatly emphasized technical competencies over general competencies.

Internships were a much more obvious complement to formal coursework and perhaps the clearest source of non-technical skill building. Although internship postings were heterogeneous data that were relatively difficult to analyze, our investigations suggested that internships, regardless of whether they were focused on social media, web development, or other kinds of supporting and development roles, provided opportunities for students to gain skills in teamwork, developing processes, engaging in customer service, learning to work with clients, and gain real work business experience.

Internship postings reflected many of the themes that emerged from our analyses of job postings, employer interviews, and employer survey results. Our research presented in this report has affirmed that employers focus on potential employee competency, regardless of its origin.

Job postings predominantly emphasized workplace skills such as professional communication; teamwork; business fundamentals. Software and application skills in terms of programming and support were also present, but were often presented in terms of supporting roles, systems analysis, and customer service. Core technical knowledge such as networking and systems administration were also present, but functioned more as initial points of entry for job postings, as opposed to the major emphasis of posting content.

In this analysis, we found that the internship postings demonstrated varying levels of context and details. While some posts provided information about the organization as well as sections detailing what the intern would be learning and the skills that would be enhanced during the internship experience, some posts contained no organization

information and provided a bulleted list of technologies the intern would potentially use (e.g., "Excel, PowerPoint, Word") and a brief list of tasks ("budgets, schedule, tasks, meetings"). The literature emphasizes the importance of accurately matching students to internships that are related to their interests and future career goals and that attracted students who did not require a great amount of skill and training (Ralevich and Martinovic 2010). Students relying on these postings to acquire an experiential learning opportunity may not have access to adequate information when seeking an internship to meet their specific needs and employers may be disappointment by the unskilled interns they receive. This finding suggests that faculty and employers need to work together to craft appropriate internship posting language and perhaps even play a more direct role in matching students to internships that would enhance and extend their skills and aspirations.

4.3 RQ3. To what extent do IT industry certifications reflect IT coursework?

Consistent with the work of previous research conducted by Al Rawi et al. (2005) and Poteat (2006), this analysis demonstrated that certain certifications fit more easily into existing IT and computing curricula than others. Often, a certification's learning objectives and exam contents will be conveyed in a sequence of courses as opposed to one course (Al Rawi et al. 2005). From the analysis of 15 IT certifications and the related University A and University B IT courses, we determined that partial certification knowledge areas for 12 out of 15 certifications were covered in existing University B courses, and 13 out of 15 certifications' knowledge areas were covered in existing University A courses.

The University B courses covered all learning objectives and exam contents for three certifications; for University A, the number of certifications for which all learning objectives were covered in the courses was two. As with University B, all certification exam contents were covered in existing University A's IT courses for the W3Schools CSS and Oracle MySQL Database Developer certifications. These findings suggest that many certifications easily fit into existing course contents and may provide students with the opportunity to be certified in those areas without curricula having to be adjusted to specifically prepare students for certifications. Findings suggest that certifications for which the objectives were partially covered in University B and University A IT courses can be made to fully provide certification contents with revisions and additions to the existing curricula.

5 Conclusion

In this assessment project, the study team sought to determine the extent to which the computing-related learning opportunities prepare students to fulfill high need IT jobs in Florida. We conclude that state college and university curricula not only reflect national curriculum standards, but also prepare students to pass the examinations linked to several desired industry certifications. When internships postings and job postings were considered in light of curricula and national standards, it appeared very likely that many internships would function as a dynamic complement to coursework and certifications and culminate in the changing blend of technical and professional skills expressed in many job postings.

Although syllabi analysis was an important aspect of curriculum examination, a limitation of this study is that it is a small portion of a much larger picture. A program's curriculum cannot be understood based only on a syllabus analysis. Additionally, while curriculum guidelines such as the ones developed by the ACM/IEEE and ACM/AIS are helpful in designing a comprehensive curriculum, programs in higher education must also respond to other factors such as faculty expertise, high school and two-year program offerings, and the needs of the local industry. These factors should be taken into account when examining a curriculum.

5.1 Preliminary pathway identification

At the conclusion of the data analysis, we used the Advance CTE *IT Career Cluster Knowledge & Skills Statements* (Advance CTE, Advance 2008), *IT Career Cluster Plan of Study* (Advance CTE, Advance 2007), and *Information Technology Sample List of Existing Credentials* (Advance CTE, n.d.) to investigate whether the study results yielded insight into and confirmed existing efforts to map potential educational pathways to the high need IT careers identified by the Board of Governors Gap Analysis report. We examined the job titles of Computer Network Architect, Computer Systems Analyst, Computer Programmer, Applications Software Developer, Systems Software Developer, and Graphic Designer. Figure 3 illustrates the process we used to map educational experiences to those careers.

As Fig. 3 suggests, the study team started with a high need job title from the Board of Governors' GAP analysis (which are presented as Bureau of Labor Statistics job titles), reviewed the Knowledge and Skills for relevant learning outcomes and Plan of Study documents for the points at which those learning outcomes should be imparted. These learning outcomes were then matched to the curriculum components in the University B, University A, and state college syllabi as well as the contents of internship experiences and sample industry certifications. This attempt to trace a path

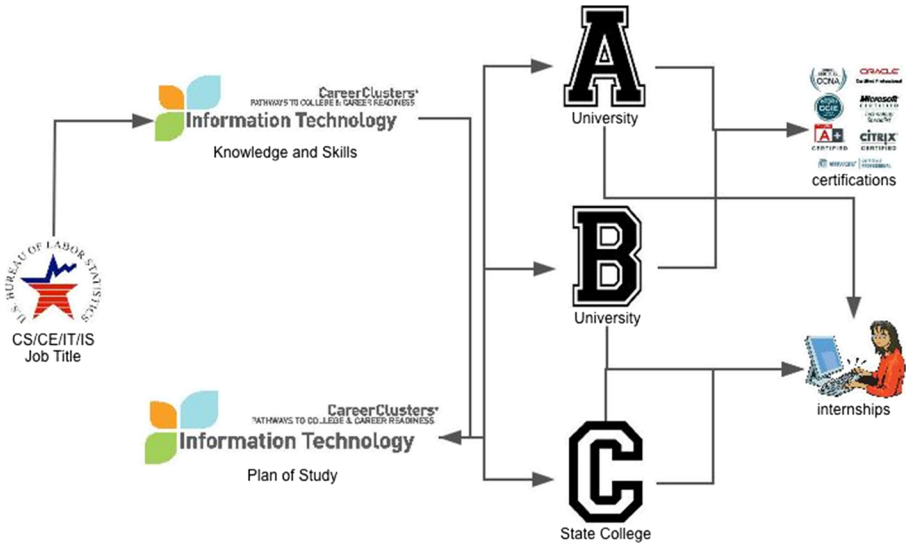

Fig. 3 Preliminary pathways identification process

from job title through plan of study through educational program suggested that, with further development, this area is fertile to document a clear link between educational experiences and employment potential.

5.2 Implications for future research

This work represents a foundational step on a research agenda. We completed the research activities with intentions for several directions for further research:

- To what extent do classroom activities represent the teamwork, collaboration, critical thinking, and problem-solving skills employers require?
- How do IT students use creative thinking and problem solving in the classroom, in internships, and on the job?
- How can internship activities be more closely tracked and aligned with specific educational outcomes?
- To what extent do employers face location specific challenges relating to attracting and retaining qualified candidates?
- At what point in a career pathway does an additional degree become important for job security and or advancement?
- What venues other than certification and internship do candidates use to augment their skills with current, high need skills? How do candidates demonstrate this additional mastery?
- To what extent does certificate attainment enhance graduates' abilities to gain employment?
- To what extent would a large scale, perhaps statewide, analysis of job postings, curriculum, certifications, internships, and employer needs reflect the results of this analysis?

As with other studies that revealed an incomplete match between the skill sets expected by employers and students' formal learning experiences (e.g., Tang et al. 2001), the results of this study suggest that internships and certifications may have a strong role to play in responding to t "the emerging information technologies [that] are also requiring a new breed of IT professional - a person who understands the needs of the business as well as IT" (Hunt et al. 2011, p. 5); these ever-changing needs complicate the efforts of IT educators to prepare students for careers in a field that is highly dynamic and places great emphasis on innovation (Downey et al. 2008). The onus for preparation is not solely on the student; as students enter college, they often wrestle with mitigating factors such as the need to work, to rely on financial aid, and or competing responsibilities of home and family. To meet their needs and workplace demands, students benefit from responsive programs that help them to navigate these competing priorities. Ongoing triangulation between curriculum, educational opportunities, and employer needs can help to ensure students' ability to navigate the pathway from school to work.

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Appendix 1 Master list of course numbers and titles

Table 8 University a syllabi course titles and credit hours

Degree Name and Course Title	Credit Hours
Bachelor of Science in Computer Science (BS CS)	
CDA 3101 Computer Concepts and Organization	3
CDA 4102 Computer Architecture	3
CIS 4250 Computer Ethics and Professional Responsibility	3
CIS 4301 Systems Analysis and Design	3
CIS 4910 Information Systems Development Project	3
CNT4504 Data Communication and Organizational Network	3
COP 3014C Fundamentals of Programming	4
COP 3060 Concepts in Advanced Application Development	3
COP 3330 Intro to Object Oriented Programming	3
COP 3530 Program, Data and File Structures	3
COP 3610 Operating System	3
COP 3710 Database Management Systems	3
COT 3100 Discrete Mathematics	3
COT 3101 Discrete Structures II	3
COT 4210 Foundations of Computer Science	3
Bachelor of Science in Information Systems (BS IS)	
CIS 1920 Professional Development I	3
CIS 3040 Information Systems in Organizations	3
CIS 4250 Computer Ethics and Professional Responsibility	3
CIS 4301 Systems Analysis and Design	3
CNT 4504 Data Communication and Organizational Network	3
COP 3014C Fundamentals of Programming	3
COP 3060 Concepts in Advanced Application Development	3
COP 3330 Introduction to Object Oriented Programming	3
COP 3530 Program Data and File Structures	3
COP 3710 Database Management Systems	3
COT 2104 Mathematics for Computing	3
ACG 2071 Managerial Accounting	3
MAN 3025 Principles of Management	3
MAR 3023 Principles of Marketing	3
Bachelor of Science in Information Technology (BS IT)	
COP 3828: Web Programming and Design	3
CIS 1920: Professional Development I;	3
CNT 2000: Computer Systems and Network Fundamentals	3
COP 3014C: Fundamentals of Programming	3
COP 3710: Database Management Systems	3
COP 3366 Introduction to C# Programming	3
COT 2104: Mathematics for Computing	3
CIS 4920 Professional Development	3

Table 8 (continued)

Degree Name and Course Title	Credit Hours
CIS 4360: Introduction to Computer Security	3
CNT 4504: Data Communication & Organizational Network;	3
CIS 4250: Computer Ethics and Professional Responsibility;	3
CNT 4603: Computer & Network System Administration;	3
CIS 4517: Needs Assessment and Technology Transfer	3
CEN 4721: Concepts and Principles of HCI	3
CIS 4945: IT Capstone Project.	3

Table 9 University B syllabi course titles and credit hours

Degree Name and Course Title	Credit Hours
BA in CS	
COP 3014 Programming I	3
COP 3353 Introduction to UNIX	1
COP 3330 Object-Oriented Programming	3
CDA 3100 Computer Organization I	3
CDA 3101 Computer Organization II	3
CEN 4020 Software Engineering I	3
CEN 4021 Software Engineering II	4
COP 4020 Programming Languages	3
COP 4610 Operating Systems & Concurrent Programming	3
COP 4530 Data Structures, Algorithms, and Generic Programming	3
COP 4710 Theory and Structure of Databases	3
MAD 2104 Discrete Mathematics I	3
BS in CS	
COP 3014 Programming I	3
COP 3353 Introduction to UNIX	1
COP 3330 Object-Oriented Programming	3
CDA 3100 Computer Organization I	3
CDA 3101 Computer Organization II	3
CEN 4020 Software Engineering I	3
CEN 4021 Software Engineering II	4
CIS 4250 Ethics in Computer Science	3
COP 4020 Programming Languages	3
COP 4610 Operating Systems & Concurrent Programming	3
COP 4530 Data Structures, Algorithms, and Generic Programming	3
COP 4531 Complexity and Analysis of Data Structure and Algorithms	3
COP 4710 Theory and Structure of Databases	3
COT 4420 Theory of Computation	3
MAD 2104 Discrete Mathematics I	3

Table 9 (continued)

Degree Name and Course Title	Credit Hours
MAD 3105 Discrete Mathematics II	3
STA 4442 Introduction to Probability	3
BS in IT	
DIG 3118: Digital Graphic Design	3
LIS 3201: Research & Data Analysis for Information Professionals	3
LIS 3706: Information Systems & Services	3
LIS 3781: Advanced Database Management	3
LIS 3784: Information Organization & Communication	3
LIS 3793: Information Architecture	3
LIS 4351: User Experience Design	3
LIS 4368: Website Development with PHP	3
LIS 4369: Extensible Enterprise Solutions	3
LIS 4480: IT Leadership	3
LIS 4482: Managing Networks & Telecommunications	3
LIS 4488: Network Administration	3
LIS 4910: Information Technology Project	3

Table 10 University A/ B joint program syllabi course titles and credit hours

Course Title	Credit Hours
EEL 3002L ECE Engineering Tools Lab	2
EEL 3111 Introduction to Circuit Analysis	3
EEL 3112 Advanced Circuits with Computers	3
EEL 3112L Advanced Circuits with Computers Lab	1
EEL 3135 Signal and Linear Systems Analysis	3
EEE 3300 Electronics	3
EEE 3300L Electronics Laboratory	1
EEL 3705 Digital Logic Design	3
EEL 3705L Digital Logic Design Laboratory	1
EEL 4021 Statistical Topics for Electrical Engineers	3
EEL 4515 Digital Communication Systems	3
EEL 4710 Introduction to FPLDs	3
EEL 4713 Computer Arch and Organization	3
EEL 4746 Microprocessor Based System Design	3

Table 11 State college syllabi course titles and credit hours

Course Title	Credit Hours
Associate in Science in Computer Information Technology	
CTS 1131 - Hardware Configuration	3
CTS 1133 - Software Configuration	3
CGS 1060 - Introduction to Information Technology	3
CGS 1100 - Microcomputer Applications for Business and Economics	3
CIS 1942 – Internship	2
CIS 2321 - Information Systems	3
CTS 2155 - Customer Support Operations	3
MAN 2582 - Introduction to Project Management	3
CNT 2001 - Computer Networks and Telecommunications	3
or CET 2600 - Network Fundamentals	3
COP 1000 - Introduction to Computer Programming	3
COP 2551 - Introduction to Object Oriented Programming with Java	3
or COP 2842 - Internet Programming	4
COP 2822 - Web Technologies	4
CTS 2437 - Introduction to SQL Server Database	3
Software Engineering Track	
COP 2220 - C Programming	3
COP 2334 - Object-Oriented Programming with C++	3
COP 2360 - Introduction to C#	3
COP 2805 - Advanced Java Programming	3
COP 2806 - J2EE Java Development I	3
COP 2837 - Introduction to Programming with Visual Basic.NET	3
COP 2823 - ASP.NET Programming	3
CTS 2149 - CAPM (Certified Associate in Project Management) Exam Prep	3
Web Track	
CGS 2555 - Introduction to the Internet	4
CGS 2820 - Web Site Design and Development	4
CGS 2821 - Advanced Web Site Design and Development	4
CGS 2825 - Web Site Management	3
Database Track	
CGS 2542 - Database Concepts for Microcomputers	3
CTS 2440 - Oracle SQL and PL/SQL	4
CTS 2441 - Oracle Database Administration	4
CTS 2445 - Advanced Oracle PL/SQL Programming	3
Associate in Science in Networking Systems Technology	
CNT 1015 - Operating Systems Foundations	3
CTS 1131 - Hardware Configuration	3
CTS 1133 - Software Configuration	3
CTS 1154 - Technical Support	3
or CTS 2155 - Customer Support Operations	3
CTS 1120 - Fundamentals of Information Security	3

Table 11 (continued)

Course Title	Credit Hours
CNT 2942 - Cooperative Education (Internship)	2
MAN 2582 - Introduction to Project Management	3
Computer Systems Networking	
CET 2600 - Network Fundamentals	3
CNT 2102 - Advanced Routing and Switching	4
CNT 2210 - WAN Fundamentals	4
CTS 2655 - Routing and Switching Fundamentals	4
Computer Forensics Technician/Network Security	
CTS 2317 - Advanced Information Security (Principles and Practices of CISSP)	4
CAP 2140 - Data Forensics I	4
CAP 2141 - Data Forensics II - Advanced	4
CNT 2404 - Intrusion Detection Systems and Auditing	4
CET 2662 - Techniques of Computer Hacking and Incident Handling	4
Information Technology Management (Systems Administration)	
CTS 1334 - Server Configuration	4
CTS 2111 - Open Source Operating Systems (Redhat Computing Essentials)	4
CTS 2329 - Desktop Configuration (Redhat System Admin)	4
CTS 2332 - Open Source Networking Systems (Redhat Network Applications)	4
Advanced Network Support Technician	
CTS 2655 - Routing and Switching Fundamentals	4
CTS 2657 - Building Scalable Networks (CCNP Route)	4
CTS 2658 - Managing Network Security	4
CTS 2659 - Building Multilayer Switched Networks (CCNP Switch)	4
CNT 2102 - Advanced Routing and Switching	4
CNT 2210 - WAN Fundamentals	4
CET 2600 - Network Fundamentals	3
Network Virtualization	
CTS 2411 - Information Storage Management	4
CTS 2370 - Virtual Infrastructure: Installation and Configuration (VMware 1)	4
CTS 2371 - Virtual Infrastructure: Deployment, Security, and Analysis	4
CTS 2372 - Virtualized Server Implementation I (Citrix XenDesktop)	4
CTS 2373 - Virtualized Server Implementation II (Citrix XenApp)	4
CTS 2302 - Directory Services Configuration	4
CTS 1334 - Server Configuration	4
Voice Over IP	
CTS 2660 - Deploying Quality of Service	4
CTS 2662 - Voice over IP (VoIP)	4
CTS 2655 - Routing and Switching Fundamentals	4
CNT 2210 - WAN Fundamentals	4
CNT 2102 - Advanced Routing and Switching	4
CET 2600 - Network Fundamentals	3
CET 2588 - Network + Certification Review	2

Table 11 (continued)

Course Title	Credit Hours
CET 2629 - Internet Troubleshooting Support (CCNP TSHOOT)	4
CNT 2401 - Networking Operating System Security	4
CNT 2930 - Special Topics in Networking (Capstone)	3
CTS 1136 - Computer Hardware and Software Certification Review	2
CTS 2664 - CCNA Security	4
CTS 2325 - Networking Services Configuration	4
CTS 2656 - Basic Routing and Switching Certification Review	2
MAN 2021 - Principles of Management	3
BAS in Information Technology Management	
CGS 1100 - Microcomputer Applications for Business and Economics	3
CIS 2321 - Information Systems	3
CNT 2001 - Computer Networks and Telecommunications	3
CET 2600 - Network Fundamentals	3
COP 1000 - Introduction to Computer Programming	3
COP 2551 - Introduction to Object Oriented Programming with Java	3
COP 2842 - Internet Programming	4
CTS 1131 - Hardware Configuration	3
CTS 1133 - Software Configuration	3
CTS 2437 - Introduction to SQL Server Database	3
MAN 2582 - Introduction to Project Management	3
BUL 3130 - Business Law and Ethics	3
FIN 3400 - Financial Management	3
GEB 3213 - Business Writing	3
GEB 4891 - Strategic Management and Decision Making	3
ISM 3013 - Introduction to Information Technology Management	3
ISM 3113 - Systems Analysis and Design	3
ISM 4212 - Database and Physical Design	3
ISM 4220 - Network Management for Information Professionals	3
ISM 4302 - Information Technology Planning	3
ISM 4480 - Electronic Commerce Systems and Strategies	3
ISM 4881 - Capstone in Information Technology Management	3
MAN 3240 - Organizational Behavior	3
MAR 4814 - Technology Marketing Management	3
B.A.S. in Computer Systems Networking and Telecommunications	
CTS 1154 - Technical Support	3
CTS 1133 - Software Configuration	3
CNT 1015 - Operating Systems Foundations	3
CTS 1131 - Hardware Configuration	3
CTS 1120 - Fundamentals of Information Security	3
CET 2600 - Network Fundamentals	3
CNT 2102 - Advanced Routing and Switching	4
CNT 2210 - WAN Fundamentals	4

Table 11 (continued)

Course Title	Credit Hours
CTS 2655 - Routing and Switching Fundamentals	4
MAN 2582 - Introduction to Project Management	3
CNT 3014 - Enterprise Systems Integration	4
CNT 3406 - Information Security Management	3
CNT 3702 - Infrastructure and Facilities Planning	4
CNT 4509 - Advanced Convergent Technologies	4
CNT 4704 - Enterprise Network Management	4
CNT 4708 - Emerging Information Technologies	4
CNT 4931 - Computer Networking Capstone	4
CNT 4940 - Cooperative Education (Internship)	2
ISM 3014 - Service Support Management	4
ISM 3013 - Introduction to Information Technology Management	3

Appendix 2

Table 12 IT Certifications covered in and missing concepts from university courses

Certification	University A Courses and Missing Certification Concepts	University B Courses and Missing Certification Concepts
Project Management Institute's Certified Associate in Project Management (CAPM)	1. Covered in: CIS 4945 Missing: Project Cost Management Project Quality Management Project Human Resource Management Project Communication Management Project Risk Management Project Procurement Management Project Stakeholder Management	Covered in: LIS 4708, LIS 4910 Missing: 1. Project Integration management 2. Project Human Resource management 3. Project Procurement Management 4. Project Stakeholder Management
CompTIA Basic A+	Covered in: CNT 2000, CNT 4504, CNT 4581 Missing: 1. Laptops 2. Printers 3. Operational procedures	Covered in: LIS 3353, LIS 4381, LIS 4482, LIS 4488, LIS 4777 Missing: 1. Laptops 2. Printers 3. Operational procedures
CompTIA Network+	Covered in: CNT 4504, CIS 4250, CNT 2000 Missing: 1. Network Installation and Configuration 2. Performance tracking tools and Monitoring tools 3. Network Architecture	Covered in: LIS 4482, LIS 4488 Missing: 1. Performance tracking tools and Monitoring tools 2. Network Architecture
CompTIA Security+	Covered in: CNT 4504, CIS 4360, CIS 4385C, CIS 4250	Covered in: LIS 4482, LIS 4488, LIS 4774, LIS 4777

Table 12 (continued)

Certification	University A Courses and Missing Certification Concepts	University B Courses and Missing Certification Concepts
	Missing: 1. Application, Data and Host Security 2. Access Control and Identity Management	Missing: 1. Application, Data and Host Security 2. Access Control and Identity Management
CompTIA Linux+	Covered in: CIS 4385C, CNT 2000, CNT 4504 Missing: 1. System Architecture 2. GNU and Unix Commands 3. Shells, Scripting and Data Management 4. User Interfaces and Desktops 5. Administrative Tasks 6. Essential System Services	Covered in: LIS 3781, LIS 4488, LIS 4777 Missing: 1. System Architecture 2. GNU and Unix Commands 3. Devices, Linux File systems, File system Hierarchy Standard 4. Shells, Scripting and Data Management 5. User Interfaces and Desktops 6. Administrative Tasks 7. Essential System Services
W3Schools HTML/HTML5	Covered in: COP 3828 Missing: 1. HTML Graphics 2. HTML APIs 3. Unicodes, encodings from HTML References	Covered in: LIS 3353, LIS 4369, LIS 4368 Missing: 1. HTML Graphics 2. HTML APIs 3. Unicodes, encodings from HTML References
W3Schools CSS	Covered in: COP 3828 Missing: None	Covered in: LIS 3353, LIS 4369, LIS 4368 Missing: None
Oracle MySQL Database Developer	Covered in: COP 3710, COP 4710 Missing: None	Covered in: LIS 3781 Missing: None
Oracle MySQL Database Administration	Covered in: COP 3710, COP 4710 Missing: 1. Availability techniques for MySQL 2. Diagnostic Data and Metadata Sources in MySQL	Covered in: LIS 3781 Missing: 1. Availability techniques for MySQL 2. Diagnostic Data and Metadata Sources in MySQL
Information Systems Security Professional (CISSP)	Covered in: CIS 4250, CIS 4360, CNT 2000, CNT 4504 Missing: 1. Access control 2. Physical (Environmental) Security	Covered in: LIS 3353, LIS 4482, LIS 4774, LIS 4777 Missing: 1. Access control 2. Business Continuity and Disaster Recovery Planning 3. Physical (Environmental) Security
VMWare Certified Associate—Data Center Visualization	No courses were identified in this program that cover certification exam objectives	Covered in: LIS 4488 Missing: 1. Explain Data Center Virtualization Concepts and How They Solve Typical Business Challenges 2. Correlate VMware Data Center Virtualization Solutions with Specific Business Challenges

Table 12 (continued)

Certification	University A Courses and Missing Certification Concepts	University B Courses and Missing Certification Concepts
Cisco Certified Network Associate (CCNA)	Covered in: CNT 2000, CNT 4504 Missing: 1. IOS 2. IPv6 3. IPv4 4. OSPF 5. Cisco licensing 6. Enhanced Interior Gateway Routing Protocol (EIGRP) 7. Serial Line Interfaces 8. Frame Relay Interfaces 9. VLANs 10. Ethernet 11. VLSM 12. Basic Traffic Filtering	Covered in: LIS 4482, LIS 4488 Missing: 1. IOS 2. IPv6 3. IPv4 4. OSPF 5. Cisco Licensing 6. Enhanced Interior Gateway Routing Protocol (EIGRP) 7. Serial Line Interfaces 8. Frame Relay Interfaces 9. VLANs 10. Ethernet 11. VLSM 12. Basic Traffic Filtering
Cisco Certified Network Professional (CCNP)	Covered in: CNT 4505 Missing: 1. Implementation of complex enterprise LAN and WAN routing solutions 2. IPv6 3. EIGRP 4. BGP 5. OSPF	Covered in: LIS 4482, LIS 4488 Missing: 1. Implementation of complex enterprise LAN and WAN routing solutions 2. IPv6 3. EIGRP 4. BGP 5. OSPF
W3Schools Certification: PHP	Covered in: COP 3710, COP 3828, COP 4710 Missing: None	Covered in: LIS 3781, LIS 4368, LIS 4369 Missing: None
W3Schools Certification: XML	Covered in: COP 3366 Missing: XML DOM and XSLT tutorial concepts	Covered in: LIS 4369 Missing: XML DOM and XSLT tutorial concepts

Appendix 3

Table 13 Job title technical and general knowledge areas and links to university b bsit course content

Job Title	Technical Competencies (n)	General Competencies (n)	University B BSIT Course
Computer and Information Research Scientist	Systems Integration & Architecture (1) System Administration (1) Platform Fundamentals (1) Integrated Platform Technologies (1)	Teamwork (1)	LIS 3201, LIS 3793, LIS 4910, LIS 4480, LIS 3706, LIS 4910, LIS 4369, LIS 4368, LIS 4369
Computer Network Architect	Systems Integration & Architecture (8) Networking (4) System Administration (3) Information Management (2) Platform Fundamentals (2)	Professional Communication (6) Problem Solving (5) Self Management (5) Teamwork (2) Flexibility (2) Business Fundamentals (3)	LIS 3781, LIS 4369, LIS 3793, LIS 3784, LIS 3706, LIS 4910, LIS 4480, LIS 4482, LIS 4488, LIS 3201
Computer Programmer	Platform Fundamentals (30) Systems Integration & Architecture (22) System Administration (11) Information Management (8) Web Systems & Technologies (6) Networking (5) Integrated Platform Technologies (4) Human Computer Interaction (4) Platform Technologies (1) Math and Statistics (2)	Business Fundamentals (14) Teamwork (5) Customer Service (6) Self Management (4) Professional Communication (4) Interpersonal Skills (3) Problem Solving (2) Flexibility (2)	LIS 3781, DIG 3118, LIS 4369, LIS 3793, LIS 3784, LIS 3706, LIS 4910, LIS 4480, LIS 4482, LIS 4488, LIS 3201, LIS 4351, LIS 4368
Computer Support Specialist	Networking (19) System Administration (7)	Customer Service (7) Professional Communication (4)	LIS 4368, LIS 3201, LIS 4488, LIS 4482, LIS 4480, LIS 4910, LIS 3706, LIS 3793, LIS 4369, DIG 3118

Table 13 (continued)

Job Title	Technical Competencies (n)	General Competencies (n)	University B BSIT Course
	Systems Integration & Architecture (7) Platform Fundamentals (3) Platform Technologies (2) Networking (1) Integrated Platform Technologies (1) Web Systems & Technologies (1)	Problem Solving (3) Flexibility (1) Interpersonal Skills (1) Self Management (1)	
Computer Systems Analyst	Systems Integration & Architecture (27) System Administration (10) Information Management (6) Platform Fundamentals (4) Human Computer Interaction (1) Networking (1) Platform Technologies (1)	Business Fundamentals (19) Customer Service (11) Teamwork (10) Professional Communication (6) Flexibility (6) Interpersonal Skills (2) Self Management (2)	LIS 3781, LIS 4369, LIS 3793, LIS 3784, LIS 3706, LIS 4910, LIS 4480, LIS 4482, LIS 4488, LIS 3201, LIS 4351
Database Administrator	Information Management (21) Systems Integration & Architecture (13) System Administration (6) Platform Fundamentals (5) Integrated Platform Technologies (1) Human Computer Interaction (1)	Business Fundamentals (5) Self Management (3) Flexibility (3) Customer Service (2) Professional Communication (2) Teamwork (1)	LIS 3781, LIS 4369, LIS 3793, LIS 3784, LIS 3706, LIS 4910, LIS 4480, LIS 3201, LIS 4351, LIS 4368
Information Security Analyst	Information Assurance & Security (18) System Administration (6) Systems Integration & Architecture (5) Platform Fundamentals (4) Networking (3)	Business Fundamentals (3) Flexibility (2) Interpersonal Skills (2) Problem Solving (2) Professional Communication (1) Self Management (1)	LIS 3201, LIS 3793, LIS 3706, LIS 4910, LIS 3784, LIS 3781, LIS 4482, LIS 4488, LIS 4351, DIG 3118, LIS 4368, LIS 4369, LIS 3706

Table 13 (continued)

Job Title	Technical Competencies (n)	General Competencies (n)	University B BSIT Course
	Math and Statisitcs (2) Human Computer Interaction (1) Information Management (1) Platform Technologies (1)	Teamwork (1) Accountability (1)	
Network and Computer Systems Administrator	Networking (29) System Administration (13) Systems Integration & Architecture (6) Information Assurance & Security (3) Information Management (2) Platform Technologies (2) Integrated Platform Technologies (1)	Business Fundamentals (8) Self Management (7) Flexibility (4) Teamwork (4) Professional Communication (2) Customer Service (1) Problem Solving (1)	LIS 3781, LIS 4369, LIS 3793, LIS 3784, LIS 3706, LIS 4910, LIS 4480, LIS 4482, LIS 4488, LIS 3201, LIS 4368
Software Developer	Systems Integration & Architecture (78) System Administration (52) Platform Fundamentals (38) Information Management (27) Integrated Platform Technologies (24) Web Systems & Technologies (18) Platform Technologies (14) Human Computer Interaction (11) Information Assurance & Security (4) Networking (4) Computer Science (3)	Teamwork (24) Professional Communication (21) Self Management (19) Business Fundamentals (18) Customer Service (16) Flexibility (13) Problem Solving (10) Business Fundamentals (9) Creative Thinking (3) Interpersonal Skills (1)	LIS 3781, DIG 3118, LIS 4369, LIS 3793, LIS 3784, LIS 3706, LIS 4910, LIS 4480, LIS 4482, LIS 4488, LIS 3201, LIS 4351, LIS 4368)

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