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Multinational perspectives on information technology from academia and industry

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ABSTRACT

As the term 'information technology' has many meanings for various stakeholders and continues to evolve, this work presents a comprehensive approach for developing curriculum guidelines for rigorous, high quality, bachelor's degree programs in information technology (IT) to prepare successful graduates for a future global technological society. The aim is to address three research questions in the context of IT concerning (1) the educational frameworks relevant for academics and students of IT, (2) the pathways into IT programs, and (3) graduates' preparation for meeting future technologies. The analysis of current trends comes from survey data of IT faculty members and professional IT industry leaders. With these analyses, the IT Model Curricula of CC2005, IT2008, IT2017, extensive literature review, and the multinational insights of the authors into the status of IT, this paper presents a comprehensive overview and discussion of future directions of global IT education toward 2025.

Categories and Subject Descriptors

• General and reference □ Surveys and overviews • Social and professional topics □ Model curricula • Social and professional topics □ Information technology education

Keywords

International IT curriculum; educational pathways; IT industry perspective; IT faculty perspective

1. INTRODUCTION

The research reported in this paper generates from an ACM/IEEE effort to update the IT2008 Curriculum Guidelines for Undergraduate Degree Programs in Information Technology [41], presently targeted to be the IT2017 model curriculum. The authors, part of Working Group 6 at ITiCSE 2015, focused on being forward thinking to capture both the current and future changes in IT.

Information technology (IT) means different things for different stakeholders. These stakeholders include industry and business sectors, academic institutions, professional and scientific societies, and students graduating from high school or technical schools interested in pursuing undergraduate degrees in IT. The academia-industry dimension is compounded by the geographic factor. High-tech professional organizations have international membership. IT degree programs are omnipresent. IT industry advances at fast pace worldwide.

To address the very large issue of multinational perspectives on IT education, the work in this paper centers on three research questions that now follow.

> *What commonalities and differences do IT curricular frameworks have in academic institutions worldwide?*
> Bachelor's academic programs frame their IT curriculum in light of their institutional mission, characteristics of their student population, and employer expectations. In addition to location, other differentiating factors include size, emphasis on post-bachelor's education, and student diversity of academic institutions.
>
> *What are the pathways into and through undergraduate IT degree programs in various parts of the world?*
> Multiple factors such as admission criteria, student academic preparedness and diversity, life experiences, and different configurations of educational pathways shape access, retention, and degree attainment across bachelor's academic programs in IT.
>
> *What is the future of IT?*
> The computing landscape is changing fast. Discoveries in university laboratories and R&D departments and industrial technological advances transform every global economic sector and society. New developments and resources are becoming available and too many sources of information will become a real challenge for the future.

In attempting to answer these queries, more questions emerged, which we elaborated on further in this research study.

2. INFORMATION TECHNOLOGY IN CONTEXT

People have dubbed this modern era as the 'information age' with reference to previous ages such as the Stone Age and the Iron Age. Indeed, wide access to computing and communication technologies has dramatically enhanced the technological progress of humankind, enabling the creation of many new technologies. Originally, IT consisted of very specialized and expensive computing and communication technologies, available to a relatively small portion of society. Early academic disciplines in this field included computer science, information systems, and electrical engineering.

2.1 Current definition of IT

There are many definitions of the term "information technology". A current definition of IT should include perspectives of globalization; multinational, multicultural and multidisciplinary teamwork; the importance of people (soft) skills, best practices, frameworks, and regulations. The definition from the 2008 IT Model Curriculum is relevant:

> "Information Technology (IT) in its broadest sense encompasses all aspects of computing technology. IT, as an academic discipline, is concerned with issues related to advocating for users and meeting their needs within an organizational and societal context through the selection, creation, application, integration and administration of computing technologies." [41]

Margaret Rouse states, "Information technology (IT) is a general term that covers all forms of technology used to create, store, exchange, and use information in various forms" [57]. An even more expansive definition is, "Information technology (IT) is the application of computers and telecommunications equipment to store, retrieve, transmit and manipulate data, often in the context of a business or other enterprise [17].

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These definitions seem to convey the all-inclusive, ever-expanding and integrative role of IT by organizations in our society. Academia on the other hand, views information technology as a path leading to an endpoint that "represents a fundamental change in the basic technology of teaching and learning" or as "…undergraduate degree programs to meet the computer technology needs of business, government healthcare, schools, and other kinds of organizations" [45].

2.2 Future definition of IT

If we back up over a hundred years and ask what the definition of electricity might entail, with today's hindsight we could say that electricity would become an enabling technology for the advancement of civilization, and that it would enable dramatic developments in all areas of civilization, even enabling the creation of previously unknown domains. Applying this to IT, we see the emergence of the internet and the web as major enablers of easy information access for all individuals (not just the cognoscenti) in all developed countries. This widespread information access has become an enabler for an increasing range of domains.

A recent study by the Bureau of Labor Statistics (BLS) shows that computer and mathematical occupations expect to increase by 17.7% by 2022. Software developers and programmers will account for 4 out of 10 new jobs in this group. The fastest projected growth of 36.5% will be for information security analysts [7]. All of the computer and mathematical occupations typically require some level of college education, and more than 3 in 4 new jobs in this group are projected to be in occupations that require at least a bachelor's degree. The dynamics of future computing occupations contributes directly to the definition of IT.

2.3 Global Perspective

Does IT mean the same thing around the world? In terms of business, research into various technology hubs worldwide seems to confirm these basic definitions. In some countries, including Saudi Arabia, the view of IT is very similar to what we have in the US [12]. Germany is one of the countries that emphasize broadcasting technologies as a part of IT. They use the term information and communication technologies (ICT) to add audio-visual production, telephone and wireless communications [23].

In looking at Israel, their emphasis on all technology and focus on IT has made them an industry leader worldwide. "Israel is home to major players in the high-tech industry and has one of the world's most technologically literate populations" [60]. It is of interest that Google Chairman Eric Schmidt said, "…Israel has the most important high–tech center in the world after the US"[1]. Similarly, in South Korea, Bloomberg News ranked South Korea number one among all nations, "…comparing a group of indicators, such as research & development capability, productivity, tech density and patent activity" [46]. Not surprisingly, South Korea has the highest "…broadband penetration in the world at 97% and is a leader in broadband speed". This is a key indicator of the role and expansion of IT in its broad definition, within their country.

China has placed special emphasis on funding for IT and research and this has resulted in national growth in this area. "IT covers a wide range of industries such as hardware, software, electronics, semiconductors, internet, telecom equipment, e-commerce, and unlimited computing services" [66]. During the last several years, Mexico has reached a more important role in the growing world industry of IT by including a wide range of products to become "the relevant variable of the knowledge society and the main driver of our times' technological and communications revolution" [10]. IT in Japan focuses on development a business strategy that utilizes IT ensuring the stable operation of the information systems to create safe and reliable service-driven industry [4].

Many developing countries including Brazil see IT as a way to create a competitive and innovative environment to promote economic development of the country [3]. The government of many developing countries support IT initiatives and make large capital investments in IT infrastructure. For example, Kazakhstan at the beginning of 2013 started a government program 'Informational Kazakhstan – 2020' [25] The program represents a strategy for further development of ICT in Kazakhstan and computerization of processes in all sectors of the economy. Chile's government has already integrated technology in education, business and government. Recently the country created a Ministry of Science and Technology to "lay the foundations to compete as a country on an equal footing with the rest of the world" [28]. For many countries in Africa, IT is more about consumption than innovation and "the knowledge acquired through the internet has already transformed several lives in the poverty-stricken areas of Africa" [36].

In understanding of the global similarity of IT, a review of leading job websites, such as http://indeed.com, shows that the same global companies (IBM, Microsoft, Cisco, Intel, etc.) hire IT professionals around the world and have the same requirements in all countries. Indeed.com aggregates job listings from different websites, including job boards, staffing firms, associations, and company career pages. The site has 180 million unique visitors every month from over 50 different countries in 28 languages.

3. SURVEY METHODOLOGY

An important question of computing disciplines is the way people come to understand computing and ways to make it better [15]. Social context is important in exploring how IT curricular frameworks reflect and respond to factors specific to the academic institutions of the IT undergraduate degree programs [62]. To gain insights into what IT discipline and profession mean to academia and industry, the authors designed two online surveys, for computing faculty and IT professionals. With support from ACM, the surveys were administered in spring of 2015.

Survey participants were faculty members in computing departments around the world and IT professionals who are members of the Association of Information Technology Professionals (AITP). The purpose of the surveys was to evaluate the curricula of undergraduate IT degree programs that prepare highly competitive IT graduates. Data in the Integrated Postsecondary Education Systems [51] identified participating academic computing programs in the U.S. ACM identified non-U.S. academic programs. One working group member reached out to the AITP to administer the IT professional survey.

The design of the faculty survey appears in Appendix A.1. It has taken into account institutional and curriculum constructs, each having four elements.

[1] http://www.israel21c.org/google-chair-eric-schmidt-recommends-investing-in-israel/

Institutional constructs

1. Location (North America, Europe, Australia/New Zealand, South America, South/Southeast/East Asia, South Africa)
2. Size of the academic IT program (as measured by the number of graduates)
3. Emphasis on post-bachelor's education (as measured by the presence of graduate programs and percentage of students who continue in grad schools)
4. Sources of external student transfers

IT curriculum constructs

5. Areas of mathematics and science subjects (believed to be necessary and actually required) and number of required math and science courses
6. Credit-bearing internship experience
7. Percentage of technical IT component of the full undergraduate degree program
8. IT knowledge areas of importance

The IT industry survey appears in Appendix B.1. It has a similar but simpler design compared to the IT faculty survey. It includes the following.

Institutional constructs

1. Location
2. Size of the IT department (as measured by the number of employees)

IT curriculum constructs

3. Areas of mathematics and science subjects (believed to be necessary)
4. IT knowledge areas of importance
5. IT graduates' skill sets of importance

The faculty survey was hosted by ACM on the Survey Monkey platform and distributed through several email blasts to the ACM membership. The survey asked 16 questions with a mix of multiple-choice and free form responses[2]. Two email blasts to contacts acquired from the International Book Information Service (IBIS) and one email blast to members of the ACM Special Interest Group for Information Technology Education produced 540 responses. The first IBS blast, in April 2015, went to 3,000 U.S. faculty members and 7,000 international faculty members from countries in Africa, Asia, Australia, Europe, and the Americas. A second blast in May 2015 targeted a different sampling of unique contacts from the same IBIS list, this time reaching 1,500 U.S. faculty members and 3,500 international faculty members.

To supplement response from U.S. programs, the survey was also posted to IT faculty from a contact list compiled by a research study on the IT faculty profile [43] (approximately 900 contacts of IT faculty in the U.S., some of whom are SIGITE members). This survey outreach resulted in additional 42 responses. Further, due to an apparent lack of response from programs based in China to the IBIS mailings, two working group members distributed a Chinese translation of the survey to participants of an IT2017 workshop in Chengdu and at another workshop in Beijing taking place in spring 2015. With 15 responses from this venue, the total survey responses were 597 (about 3.8 % response rate).

For the industry survey (Appendix B.1), leaders of AITP emailed the survey to approximately 1,870 of its members with 93 respondents (5% response rate).

The survey responses were given routine data cleaning by a statistician to eliminate spurious responses, to correct typographical errors and expand common abbreviations in free-text responses, and to recode "other" responses into admissible answers when possible. Appendices A.2 and B.2 have summaries of the faculty and industry survey results.

In trying to ascertain the multinational breadth of IT curriculum frameworks, the authors investigated the survey results in the context of a literature review of previously published pedagogical work. The review of literature yielded results that were consistent with survey results. Additionally, certain findings from the survey led to investigative search terms in the literature review.

The group also investigated pathways toward a bachelor's degree in IT and considered the rigor of IT programs. The group defined a "demanding" program as one that requires some sciences beyond general education, three or more math courses, and in which more than 50% of the program is technical. It hypothesized that fewer students transfer into demanding programs as compared with transfers into non-demanding programs. If a program is too demanding, students may be less likely to graduate. Another factor we examined is the diversity of educational background. If there are many students transferring into the program from a variety of academic backgrounds, then such a group might be less likely to succeed.

The working group researched the extent to which characteristics of academic institutions correlate with characteristics of IT curriculum requirements such as required internship, size of the IT portion of the degree, and math and science course requirements. The hypotheses of interest in this study were:

a. Internship experience is highly valued in IT programs.
b. Programs with IT components that represent 65% or more of the full undergraduate degree program require more math and science courses.
c. Programs that are "demanding" have fewer transfer students,
d. Small companies pay more attention to applied calculus and linear algebra than big companies, while the latter care about probability and statistics more,
e. IT industry values social skills.

The working group also compared faculty and IT professionals' responses to evaluate the degree of match between what academic institutions and industry expect of IT degree programs.

To investigate the future of IT, the working group decided to use elements such as indicators and surveys, predictors, and information related to IT departments. One approach was the use of the results of the IT2017 industry survey to garner information on the future of IT. Specifically, it focused on the query that stated, "Indicate the top six skill sets you believe your organization will require of new IT graduates in the mid-2020s." The survey presented thirteen choices that included project management, cloud computing, data analytics, database, administration and architecture, information (cyber) security, quality assurance, PC/desktop support, networking, programming, help desk support, soft skills, and rudiments of finance. A provision for "Other" was also possible. Several chief information officers (CIOs) developed these skill sets.

2 http://www.acm.org/education/it2017_survey.pdf/

The working group also recognized that it was important to establish reliable predictors on the future of IT and explored the specific organizations that studied future trends and patterns for commercial industries. Two sources clearly emerged, namely the Gartner Group[3] and Forbes[4]. These and other sources were useful in predicting patterns for the future of computing and IT. The group found many discussions about strategic IT predictions during the research. The question remains relevant, namely: are there reliable predictors of what IT will look like in 2025? The main considerations are what will be important for future of IT. The group considered customer demand (for creating more data), industry demand (for analyzing data), and privacy and security issues.

4. RESULTS AND DISCOVERY

4.1 Curricular Frameworks

Information technology is a very broad and diverse field. Because of the diversity, it should be possible for any student from any background to map their own career path through the many topics provided in the IT curriculum; the curriculum should be capable of expanding to include the next latest new technologies. However, because of this diversity, it is also very difficult for academics to define clear requirements for a degree. In this paper, we present our research into where we believe IT education should be in the 2020s.

The CC2005 Overview Report [11] compares five computing programs that have produced model curricula. It provides an explanation of information technology as described in 2005. In their paper, Ekstrom and Lunt [22] noted several implications for IT pedagogy into the future. Williams [64] stressed the importance of incorporating the requirements of hiring IT personnel and corporate research agendas into the IT programs. Impagliazzo and McGettrick [30] considered new models and integrative approaches for developing a curriculum from an organization point of view. Degree programs in IT arose because degree programs in other computing disciplines were not producing an adequate supply of graduates capable of handling these very real needs [42]. IT programs exist to produce graduates who possess the right combination of knowledge and practical, hands-on expertise to take care of an organization's IT infrastructure and support and assist the people who use IT solutions [31, 37, 38].

4.1.1 Global Perspectives

In looking at IT academic programs globally, we noted a wide variety of approaches to teaching this discipline. Many countries, including Saudi Arabia and China, follow IT2008 curriculum [41], while other countries have their own perspectives based on their national IT industry needs. IT education has become a high priority area for the Chinese government due to China emerging as one of the most dynamic IT markets in the world. The Ming Zhang and Long Zhang [66] introduced the progress, objectives and curricula of eight IT-related programs at the bachelor's level. In Saudi Arabia, IT programs focus on areas far beyond programming or immersive software development, and integrate an intense exposure to mathematics and science to generate strong critical thinking graduates. In addition, programs provide the potential to conduct projects, internships, and research together with an emphasis on training components to enhance the practical experience of students. IT programs also foster adaptability to change in job market needs by providing in-depth knowledge through specific concentrations that are easily interchangeable [32]. Hence, respected IT programs in Saudi Arabia have enjoyed success with these principles and they serve as models for other IT programs in the region to emulate.

The growing need for IT graduates in Canada is raising concerns [44]. Compounding this challenge is an ICT sector unemployment rate of three per cent versus the national average of 7.5 per cent for all other sectors and the continued emergence of ICT sectors in segments such as the mobile arena, cloud computing and creative online content [2]. Canada's universities make use of advisory councils to inform their computer science curricula. Canada's post-secondary colleges and institutes look to industry as well for guidance on IT curriculum learning outcomes and related content, particularly when designing for the actual IT skills set.

Interestingly, in some countries such as Japan, IT as a discipline consists of several categories: strategist, system architect, project manager, service manager, global specialist and business architect [4]. The degree "010300 bachelor programming and information technologies" approved by the Russian Education Council focuses on "developing efficient computational methods and technologies, intended for implementation using parallel, distributed information resources, modeling, improvement, and maintenance of distributed information and computer systems based on advanced mathematical methods, and on efficient computer technologies" [18].

IT education in Finland has the emphasis on software engineering, communication networks and applications, smart systems, and mobile solutions [1]. In Argentina, Information Technology engineering prepares students "to define and assess projects in terms of requirements of hardware, software based and application, human resources, costs and efficiency at management" [34]. The degree specifically emphasizes that the graduates will control projects from very beginning until the final implementation. Universities in Germany recognize that "information technology has become a vast field that they cannot wholly cover by the classic programs of informatics or electrical engineering anymore" [23].

Bowen and Spohrer [5] report that both computer technology and the IT industry have undergone dramatic change and this requires that IT education must also undertake dramatic change. Cooper, Grover, and Guzdial [15] observe that "The economic value of knowing computing is greater than any other STEM field, but computing is the least diverse of all the STEM fields. Thus, too many people are losing out on the advantages of computing. We have to figure out how to fix that, while still answering the fundamental questions of our discipline. How do people come to understanding computing, and how can we make it better?" IT education is very important worldwide. As the IT industry is constantly evolving and new technologies continuously emerge, IT jobs are evolving and new positions created. "The new technologies create new ICT positions … ICT graduates today can pursue a large range of ICT careers" [8].

The structure and format of IT programs vary significantly from institution to institution and by country (Table 4.1). For example, in Saudi Arabia, King Saud University [14] and Al Imam Mohammad Ibn Saud Islamic University [32] require five mathematics courses, which represent about 14% of total of IT program credit hours. These courses include topics in discrete structures, calculus, linear algebra and differential equations, and

[3] http://www.gartner.com/technology/home.jsp

[4] http://www.forbes.com/forbesinsights/

probability & statistics. Both universities require only one science course, which is general physics that forms about 3% of the total of IT program credit hours. IT courses represent 45-49% of total of IT program credit hours in these universities.

Table 4.1. Structure of IT programs in different countries

University Name	Country	Total credit hours	Math courses credit hours	Science courses credit hours	IT course credit hours
King Saud University	Saudi Arabia	131	15	4	64
Al Imam University	Saudi Arabia	132	18	3	60
University of Cincinnati	United States	120	11	6	72
Purdue University	United States	120	9	6	52

In the United States for example, the University of Cincinnati in Ohio [33] requires three mathematics courses, which represent 9% of total of IT program credit hours. These courses include topics about discrete math, pre-calculus, and applied statistics. Students must complete 6 hours of science electives from the biology, chemistry, physics or geology discipline that form 5% of the total IT program. For the IT courses, they represent 60% of total of IT program credit hours.

Purdue University in Indiana [56] requires three mathematics courses, which represent 8% of total of IT program credit hours. These courses include topics in applied calculus, and statistics. The university has two selective science courses that form 5% of total of IT program credit hours. IT courses represent 43% of total of IT program credit hours.

From these examples, we can conclude that Saudi Arabia universities have a greater emphasis on mathematics courses while universities in the United States have a greater emphasis on science courses. The percent of IT courses varies from institution to institution regardless of country. Table 4.1 shows a summary of these findings.

4.1.2 Survey Results

4.1.2.1 Institutional Size and Geographic Location

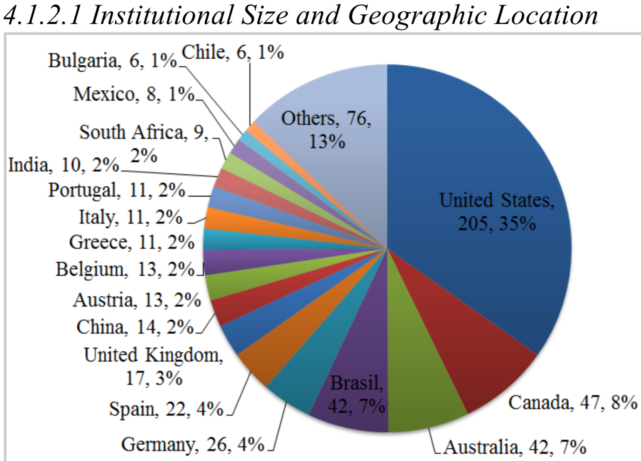

Figure 4.1. Country of origin of academic institutions of faculty respondents

The 589 faculty members who participated in the faculty survey came from 50 countries, 34.8% from U.S. and 65.2 % from non-U.S. countries. Participation from top ten countries amounted to 75% of all participants (Figure 4.1).

Data from the industry survey show that almost all industry respondents (91 IT professionals) were from U.S. (98.9%).

A majority of academic institutions (53.3%) had less than 100 graduates from their IT degree programs in the past year, and few academic institutions (12.9%) graduated more than 300 students (Figure 4.2).

A large majority of IT departments who participated in the IT professional survey had less than 30 employees (65%) and 30% were large IT departments with more than 100 employees (Figure 4.3).

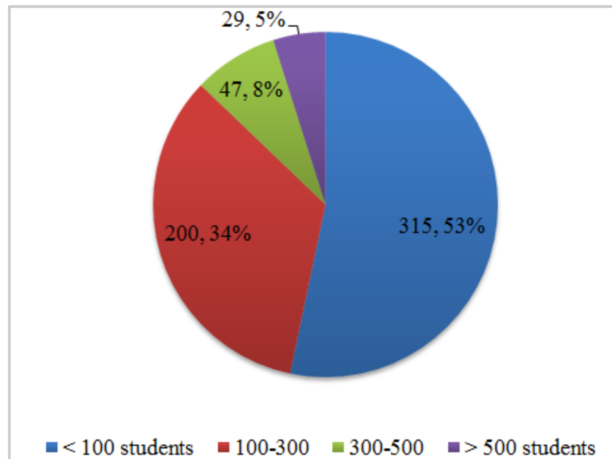

Figure 4.2. Size of IT academic programs based on the number of graduates in 2014-2015

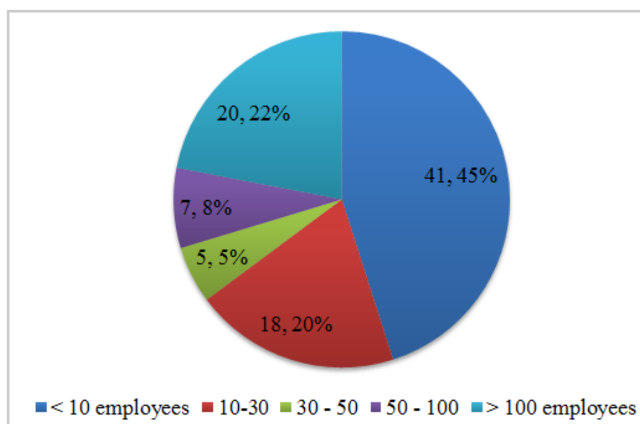

Figure 4.3. Size of IT industry departments based on the number of employees

4.1.2.2 Transfer Students and Post-Baccalaureate Education

Of the 589 respondents to the faculty survey, 537 answered the question regarding sources of external transfer students into an undergraduate IT program. As shown in Figure 4.4, approximately one-third of respondents have no significant number of transfer students; one-third has two- or three-year technical or community colleges as the primary source of transfer students. Less than 10% of respondents indicated the primary source of transfer students as being due to life experiences or industry-university articulation agreements, respectively.

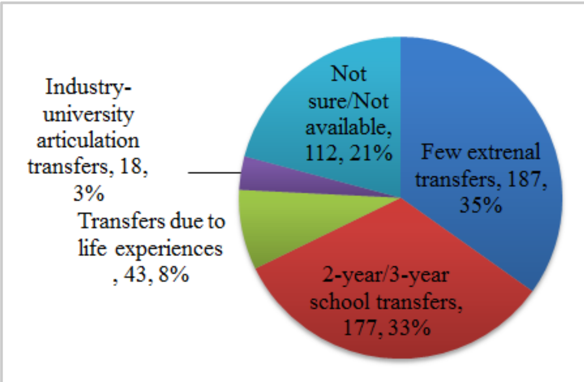

Figure 4.4. Sources of transfer students into IT academic programs

A majority of academic institutions (54%) had fewer than 10% of their graduates continue in graduate school in the past year as illustrated in Figure 4.5.

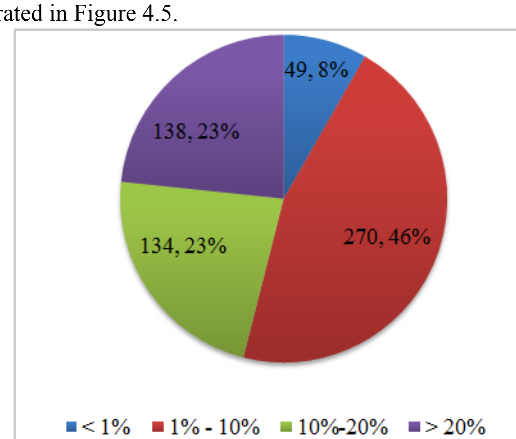

Figure 4.5. Students in IT academic programs continuing to graduate school

4.1.2.3 Mathematics Requirements

The faculty survey included the question "Which areas of mathematics does your program currently require to produce a competent IT graduate?" (Appendix A.1, F7), followed by a list of seven prompted mathematical areas (Table 4.2).

Table 4.2. Mathematics content requirements, whole survey

Topic	Total counts	Overall rank	US count	US rank
Discrete mathematics	395	1	113	2
Statistics	374	2	133	1
Applied calculus	318	3	98	3
Linear algebra	288	4	53	5
Probability	286	5	67	4
Finite mathematics	110	6	35	6
Business mathematics	82	7	27	7

Among the prompted mathematics content areas, Table 4.2 compares the counts and ranking between all faculty and US faculty.

US rankings were very similar to those of all respondents, interchanging two pairs of items of adjacent rank on both lists: discrete mathematics and statistics, and linear algebra and probability. To compare responses on ranking lists of the same corresponding items, we used the Spearman's "squared differences" statistic as an index of agreement. The two lists score +0.93 on a scale of -1 (perfect disagreement, inverse rankings) to +1 (perfect agreement, identical rankings), which is a near-perfect agreement for the US and world rankings.

Both faculty and industry surveys asked: "For a strong and rigorous undergraduate degree program in information technology, indicate the areas of mathematics you believe are necessary to produce a competent IT graduate in the mid-2020s. Check all that apply" (Appendix A.1, F6 and Appendix B.1, I4). The two surveys listed slightly different response prompts: Financial Modeling was listed only in the industry survey; Business Mathematics in the faculty survey was named "Business Mathematics/Calculus" in the industry survey.

Faculty and industry rankings of the seven matched mathematics areas showed reasonable degree of agreement (Spearman's index value of +0.54). The top math area for both groups was Statistics, and the last area was Finite Mathematics. The areas that polarized the two groups the most were Discrete Mathematics (ranking fifth on the industry list and second on the faculty's) and business mathematics (ranking second on the industry list and sixth on the faculty list).

4.1.2.4 Internship Experience

Another question asked of faculty participants, "For the undergraduate information technology program at my institution, a credit-bearing internship experience is:", had three possible responses: Required, Optional and Not offered (Appendix A.1, F12). Table 4.3 shows the number of each response received from United States and non-United States participants, and percentages of total responses from each location.

Table 4.3. Internships in undergraduate programs

Internships	US	%	non-US	%
Required	44	24%	129	37%
Optional	116	62%	156	44%
Subtotal Available	160	86%	285	81%
Not Available	27	14%	68	19%
Respondents	187		353	

Credit bearing internships for undergraduates are widely available throughout the faculty surveyed group. Respondents from the United States are more apt to require the experience, when it is available, compared with respondents from the United States. From an industry perspective, the use of an internship by students who will be potential employees is always welcome. Such an experience allows a company to view first-hand the potential of a student to become an employee of the internship sponsoring organization.

4.1.2.5 Technical IT Component of the Full Degree Program

The faculty survey asked, "For the undergraduate information technology (or closely related) degree program at your institution, the technical (IT) component of the full degree program is approximately:" (Appendix A.1, F14). As possible answers, the survey offered four ranges (Table 4.4).

Table 4.4. Technical (IT) portion of undergraduate degrees

"... of the total program"	US	%	non-US	%
Less than 30%	29	16%	46	13%
Between 30% and 50%	82	44%	67	19%
Subtotal 50% or below	111	59%	113	32%
Between 50% and 65%	51	27%	128	36%
Over 65%	25	13%	112	32%
Respondents	187		353	

540 participants answered the question. Most respondents, 86% of those surveyed, reported requiring at least 30% of a student's degree coursework to be devoted to the major subject, with little difference between the United States (16%) and the rest of the world (13%) in the proportion of responses reporting the lowest percentage category. However, above that lowest category, there was a dramatic contrast between the United States, where a comfortable majority of responses required 50% or less concentration on the major subject, compared with the rest of the world, where more than two-thirds of responses required more than 50% concentration.

4.1.2.6 IT Knowledge Areas of Importance

The faculty survey requested participants to "Consider the following list of knowledge areas for information technology as developed by the IT2017 Task Group. Indicate the 8 most important areas you believe will be essential or fundamental for IT graduates to know in the mid-2020s" (Appendix A.1, F13).

Table 4.5. US and non-US faculty ranking of knowledge areas

Knowledge area	Total counts	Overall rank	non-US rank	US rank
Programming	442	1	1	3-4
Web Systems &Technologies	405	2	2	1
Networking	367	3	6	2
Big Data	353	4	3	6
Cloud Computing	341	5	5	5
Human Computer Interaction	327	6	4	10
Information Assurance & Cybersecurity	309	7	9	3-4
Information Management	275	8	7	8
Cybersecurity: Digital Forensics & Response	271	9	8	7
System Integration & Architecture	233	10	10	11
Social & Professional Issues	205	11	12	12
Internet of Things	182	12	11	14
System Administration & Maintenance	181	13	15	9
Virtualization	175	14	13	13
Integrative Programming Technologies	130	15	14	15
Platform Technologies	86	16	17	16
Green Computing	79	17	16	17

Table 4.5 shows the response prompts along with total counts and rank values among the 17 prompted responses from US and non-US faculty. 540 participants responded to this survey item: 186 from the U.S. and 354 from the rest of the world. The table lists the knowledge areas in decreasing order of total counts (and overall rank values). "Cybersecurity: Digital Forensics & Response" offers a reminder that ranking is not an average quantity. Although this item is among the top eight for both subgroups (US rank 7 and non-US rank 8), it fell lower in rank for the entire population (overall rank 9).

The Spearman's index value of +0.82 shows a reasonably high degree of agreement between US and non-US importance rankings of the 17 knowledge areas among faculty respondents. Both groups have higher degree of agreement for their respective top six areas, which include the top five areas overall. Similarly, both groups have relatively stronger agreement for their respective last nine areas, which include the last eight areas overall (ranked 10 to 17).

The industry survey asked the same question (Appendix B.1, I6) as the faculty survey (Appendix A.1, F13) about the top 8 most important knowledge areas. 541 faculty and 91 industry participants responded to this item. We note that two areas have slightly different names in the two surveys: "Cybersecurity: Digital Forensics and Response" in the faculty survey was named "Cybersecurity and Digital Forensics" in the industry survey, and "Information Assurance and Cybersecurity" in the faculty survey was named "Information Assurance and Security" in the industry survey.

Table 4.6. Industry and faculty ranking of knowledge areas

Knowledge Areas	Industry Counts	%	Faculty Counts	%
Cybersecurity and Digital Forensics	68	75%	271	50%
Cloud Computing	59	65%	342	63%
Web Systems & Technologies	58	64%	405	75%
Virtualization	55	61%	233	33%
System Integration & Architecture	55	60%	176	43%
Information Assurance & Security	54	59%	310	57%
Information Management	53	58%	275	51%
Networking	50	55%	368	68%
Programming	45	50%	443	82%
Social & Professional Issues	45	50%	205	38%
Big Data	44	48%	353	65%
Human Computer Interaction	41	45%	328	61%
Internet of Things	34	37%	182	34%
System Administration & Maintenance	33	36%	181	34%
Integrative Programming Technologies	26	29%	130	24%
Platform Technologies	20	22%	86	16%
Green Computing	18	20%	79	15%

Table 4.6 shows the 17 knowledge areas (as named in the industry survey) with counts and percentages of respondents who selected each item in both surveys. Both surveys included a free-text "Others (please specify)" option (not shown in Table 4.6). The table lists the knowledge areas in decreasing order of preferences expressed by industry participants. Despite slight dissimilarities in

naming two knowledge areas, the Spearman's index value of +0.52 shows a reasonable degree of agreement between industry and faculty importance rankings of the 17 knowledge areas.

4.2 Educational Pathways

The faculty survey asked, "Excluding first-time admission to an undergraduate program, indicate the principal source of significant external student transfers to the information technology (or closely related) program at your institution." Of the 537 faculty respondents, 186 were from U.S. institutions, representing 35% of the pool. Compared to the survey responses as a whole, there is a dramatic difference in transfers for U.S. programs: 57% of respondents indicating any transfer source are from the U.S., and 69% of respondents indicating two- and three-year schools as the primary transfer source are from the U.S.

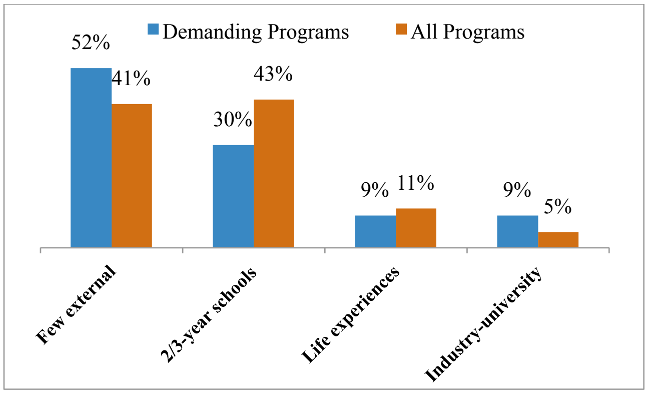

Figure 4.6. Sources of transfer students for smaller academic IT programs (<100 graduates in 2014-2015)

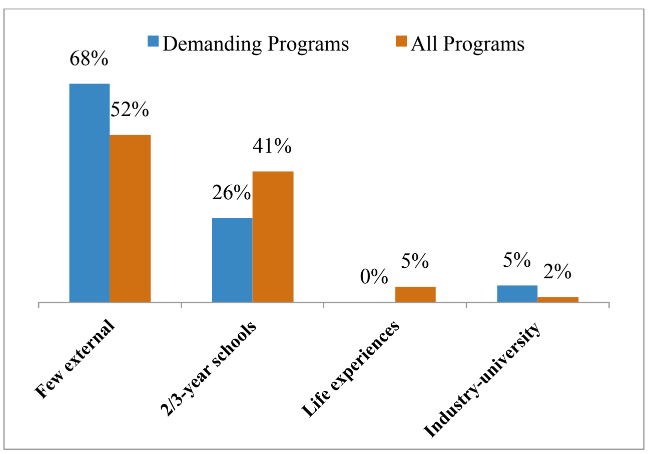

Figure 4.7. Sources of transfer students for larger academic IT programs (>300 graduates in 2014-2015)

For subsequent results, we considered a subset of the population of respondents representing "demanding" programs, where a demanding program is a program that requires some sciences beyond general education, three or more math courses, and requires more than 50% of the program is technical. According to this definition, 141 of the 589 responding programs are demanding, representing 23.9% of the institutions surveyed. See Appendix C for tables breaking down the faculty survey data on sources of external transfer students for demanding and all programs based on various program characteristics.

Figures 4.6 and 4.7 show the sources of transfer students for demanding programs (left bar, blue) and all programs (right bar, red) for small and large IT programs, respectively, as measured by the number of graduates in the 2014-2015 academic year. As compared with all schools, more of the demanding programs of any school size report few external transfer students. Fewer demanding programs report transfers from 2-year and 3-year schools, and more report industry-university articulation as their primary source of transfers, as compared with all programs. As compared with smaller programs (<100 graduates in 2014-2015), more of the larger programs (>300 graduates) report few external transfers.

Table 4.7. Sources of transfer students for academic IT programs with <30% technical content

Sources of transfer students	All Programs	Demanding Programs
Few external	44%	0%
2/3-year schools	41%	0%
Life experiences	13%	0%
Industry-university articulation	2%	0%

Table 4.8. Sources of transfer students for academic IT programs with 30%-50% technical content

Sources of transfer students	All Programs	Demanding Programs
Few external	35%	0%
2/3-year schools	52%	0%
Life experiences	8%	0%
Industry-university articulation	5%	0%

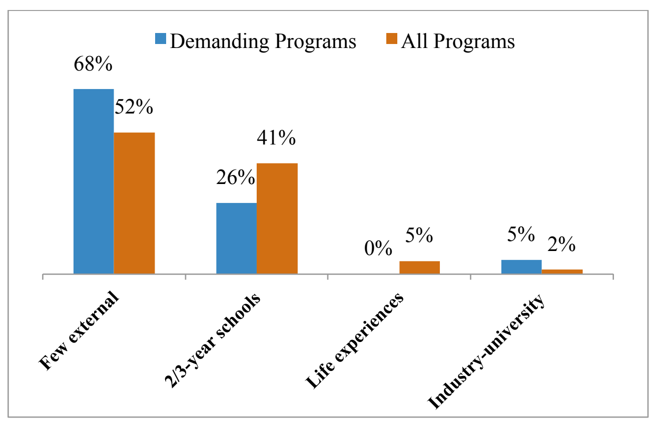

Figure 4.8. Sources of transfer students for academic IT programs with 50%-65% technical content

Among programs that have a significant source of transfers into the program, two- and three-year schools were the most reported primary source. Tables 4.7 and 4.8, and Figure 4.8 show the sources of transfer students for demanding programs and all programs broken down by the percentage of technical content in the program. By definition the demanding programs have over 50% technical IT content, so they do not appear in Tables 4.7 and 4.8 which show transfers sources for programs with <30% and 30-50% technical content, respectively.

For the most technical programs (>65%, Figure 4.9), we find a greater percentage of respondents report few external transfer students. Two- and three-year schools are still the primary source of transfers for the highly technical programs that report transfers, although industry-university articulation has greater representation than in less technical programs.

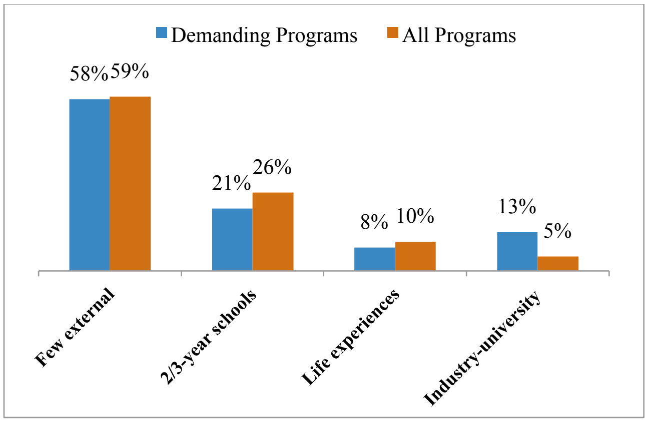

Figure 4.9. Sources of transfer students for academic IT programs with >65% technical content

4.3 Future of IT

We now present results of investigations on the future of IT. As before, these results reflect areas of indicators and surveys, predictors, and information related to IT departments. We now describe these results.

4.3.1 Indicators and Surveys

The results of the IT professionals industry survey (Appendix B Industry Survey Results) show that out of 93 responses (almost all from the United States), project management was by far the number-one skill required with 78.0% of the respondents indicating that skill. The next most important skill was information (cyber) securing with 73.6% of the respondents favoring that skill. The next four important skills expected for the mid-2020s were soft skills, business analytics, database administration and architecture, and data analytics, with responses of 64.8%, 59.3%, 51.6%, and 49.5%, respectively. Only six respondents suggested topics other than those mentioned above. These include business process management, application management, IT infrastructure and architecture/design, web systems and technologies, writing, analytical thinking, and regulatory compliance.

Cloud computing is a technology which combines the internet, web browsers and rich applications in one. To provide a cloud-based service, a provider uses cluster of servers to offload processing or storage for a user [57]. The working group used the IT2017 industry survey and a web search to ascertain the importance of cloud computing in the mid-2020s. The outcome was enlightening. Both the industry survey and the web search revealed similar results, namely, that cloud computing is not on the radar for the future. In fact, the industry survey rated cloud computing with only 42.9% favorability. Industry seems not interested in the future of the cloud as a promising investment. The "2013 Future of Cloud Computing – 3rd Annual Survey Results" painted a soft picture on what was once a promising area of technology. A fact-based story that disrupted conventional wisdom forced a major consulting firm[5] that it should not jump on the cloud bandwagon. The Wall Street Journal published an article in 2014 titled, "Forget 'the Cloud'; 'the Fog' Is Tech's Future" there provides further evidence that the cloud will not be a dominant skill in the future of information technology [49].

4.3.2 Predictors

The analysis attempts to describe how IT predictions often turn out to be 'wrong', it appears there is no obvious decline in the number of predictions made, the appetite for this kind of knowledge, or the standing of those producing this kind of insight. The authors discussed the main question of the section: What are the main predictors? The survey results indicated the top five skills sets selected; we then researched them as the main predictors for 2025: 1) project management; 2) cybersecurity; 3) soft skills; 4) business analysis; 5) database admin and architecture/ data analytics.

4.3.2.1 Project Management

We can define project management or IT project management as a process of planning, organizing and delineating responsibility for the completion of an organizations' specific IT goals[6]. Additionally, IT is the use of any computers, storage, networking and other physical devices, infrastructure and processes to create, process, store, secure and exchange all forms of electronic data.

Phillips describes an IT as especially slippery because it is always moving, changing, adapting and challenging business, as we know it [55]. IT project management is further complicated by shifting business needs and demanding stakeholders. Because good IT project management is difficult to execute, a CIO has put together this guide to understanding IT project management that includes an overview of what is required for successful project management as well as additional technology resources to learn more about it.

An IT project is any information technology project that has an assigned start and end date, often with specific milestones and goals to meet during the development cycle. These are temporary, short-term efforts to create a unique product, service or environment such as removing old servers, developing a custom ecommerce site, creating new desktop images or merging databases. Phillips (2014) presents IT projects that are constrained by three factors: time, cost and scope. For a project to be successful, these three constraints (often called the Triple Constraints of Project Management) must be in equilibrium. If any constraint is out of balance, the project is headed for disaster. All projects, IT or otherwise, move through five phases in the project management lifecycle, i.e. Initiating; Planning; Executing; Monitoring and controlling; Closing. Each phase contains processes that move the project from idea to implementation.

4.3.2.2 Cybersecurity

The increasing dependence on information and communication technologies (ICT), especially the internet and internet services, is one of the biggest challenges for cyber security. Cybersecurity has complex issues affecting many application domains and straddling many disciplines and fields. Securing the critical infrastructures requires protecting not only the physical systems, but also the cyber portions of the systems on which they rely. The most significant cyber threats are fundamentally different from those posed by the "script kiddies" or virus writers who traditionally have plagued users of the internet.

5 http://www.dworin.com/north-bridge-venture-partners-and-the-future-of-cloud-computing/

6 http://searchcio.techtarget.com/

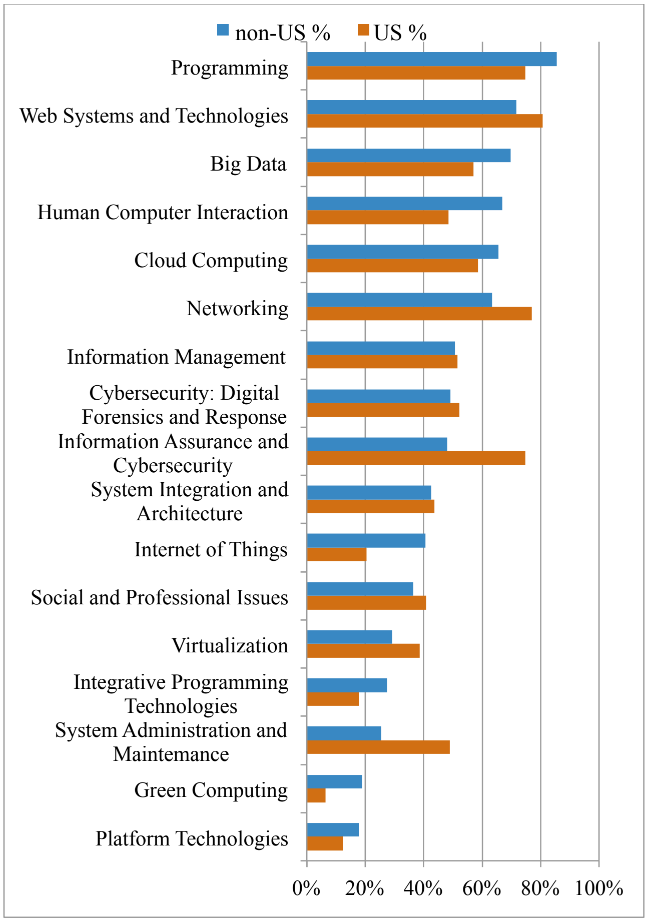

Figure 5.1. Comparison of US and non-US faculty ranking of knowledge areas

4.3.2.3 Soft Skills

Some universities are attempting to address the need for soft skills as part of what is termed user advocacy. They are working with students to make them realize the importance of interpersonal skills in their future career. As we have learned in the 2008 Model Curriculum [40, 41], communications, teamwork and ethics are necessary skills for IT career success. Making students realize that they need to incorporate these skill sets in their relationships with users and team members is crucial to a student's complete education. Educators have a responsibility to their students to make them realize that technical education alone will not help them in gaining a job - they must learn to become part of a team and put themselves in the place of the user and their fellow team members. IT professionals should not be isolated in their areas of expertise, they must have the ability to work with different constituencies within the enterprise, effectively communicate their ideas, possess project management skills and give successful presentations.

4.3.2.4 Business Analysis

The fourth skill indicated by industry as important for the future is business analysis, defined as "Business analysis is the set of tasks and techniques used to work as a liaison among stakeholders in order to understand the structure, policies, and operations of an organization, and to recommend solutions that enable the organization to achieve its goals. Business analysis involves understanding how organizations function to accomplish their purposes, and defining the capabilities an organization requires to provide products and services to external stakeholders. It includes the definition of organizational goals, how those goals connect to specific objectives, determining the courses of action that an organization has to undertake to achieve those goals and objectives, and defining how the various organizational units and stakeholders within and outside of that organization interact" [29].

Hand in hand with project management, business analysis is an integral step in the complete life cycle of a project - providing important analysis as well as monitoring and controlling a project's variables.

4.3.2.5 Data Administration/Big data

Gartner Research[7] shows that companies capture trillions of bytes of information about their customers, suppliers, and operations, and they embed millions of networked sensors in the physical world in devices such as mobile phones and automobiles, sensing, creating, and communicating data. Multimedia and individuals with smartphones and on social network sites will continue to fuel exponential growth. Big data—large pools of data captured, communicated, aggregated, stored, and analyzed—are now part of every sector and function of the global economy.

Although the formulation of problems in processing big data in different subject areas differs, there may be common approaches to the technologies for their processing. They base these approaches on proven toolsets, which may require some adjustment or adaptation in each case. The IT specialist in the processing of big data must resolve these problems (e.g., through extensive use of MapReduce, Hadoop, time-series analyses, and/or future data-mining techniques).

5. DISCUSSION

5.1 IT Curriculum Perspectives

5.1.1 U.S. and non-U.S. Faculty Comparison

US and non-US faculty groups had in common seven of their top eight most important knowledge areas: Programming, Web Systems and Technologies, Networking, Big Data, Cloud Computing, Information Management, and Cybersecurity: Digital Forensics and Response (Figure 5.1).

Among the top eight areas with overall rank 1 to 8 (Table 4.5), the largest difference of support between the US and non-US faculty groups was for Human Computer Interaction and Information Assurance & Cybersecurity knowledge areas. The occurrence of the word "cybersecurity" in two knowledge areas, "Information Assurance and Cybersecurity" and "Cybersecurity: Digital Forensics and Response" might explain the difference. US faculty selected both these areas among their top seven areas. Non-US faculty voted for one of them, "Cybersecurity: Digital Forensics and Response" and made room for "Human Computer Interaction" among their top four preferences.

5.1.2 Faculty and Industry Comparison

Faculty and industry groups had six areas with 50% or more support from their respondents: Cybersecurity and Digital Forensics, Web Systems and Technologies, Information Assurance and Security, Information Management, Networking, and Programming (Figure 5.2). Among these six areas with majority support from both groups, "Programming" and "Cybersecurity and Digital Forensics" have the most polarized

7 http://www.gartner.com/technology/topics/big-data.jsp

support. The two groups' most pronounced disagreement was for two areas with majority support only from industry: "System Integration and Architecture" and "Virtualization"; and two areas with faculty-only majority support: "Big Data" and "Human Computer Interaction".

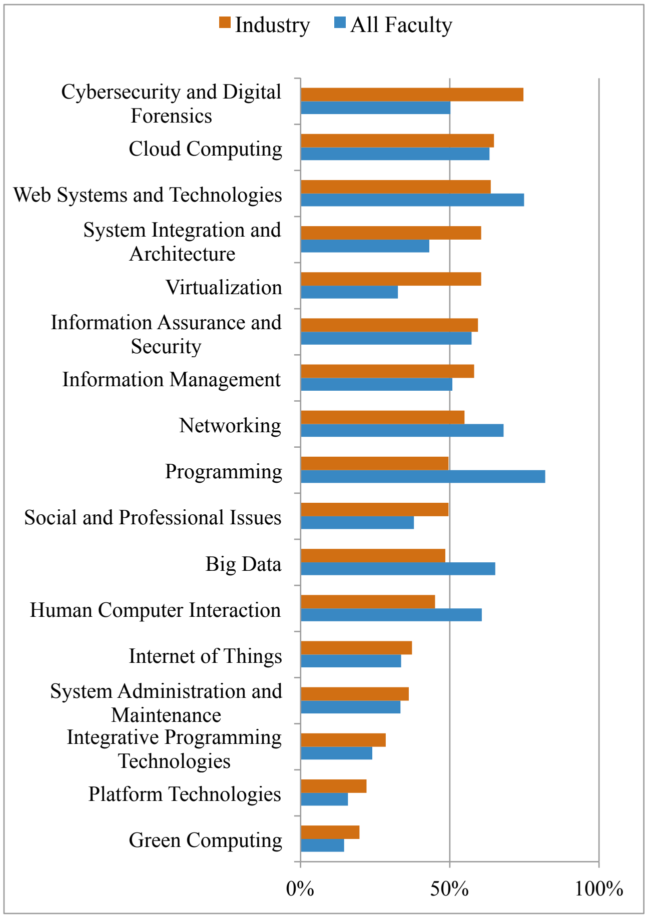

Figure 5.2. Comparison of industry and faculty ranking of knowledge areas

5.2 Educational Pathway Comparisons

From the survey results presented, we note that significantly more U.S. IT programs take transfer students (from any source) compared with the population of all programs. Furthermore, when it comes to the mechanism of transfer, significantly more U.S. IT programs selected 2-year and 3-year schools as the primary transfer source.

5.2.1 U.S. Educational Pathways

The traditional pathway into any college degree program is entry after high school, though the preparation and requirements for college entry may vary from country to country. In the United States, there is a growing emphasis on computing education throughout a child's K-12 experience, with the prospect of leading to more students choosing computing as a career. As noted in the ACM pathways report [39], computing jobs are among the fastest growing areas of employment in the U.S., and access to computer science for K-12 students needs to be expanded. One organization helping to meet the challenge is Code.org, whose vision is that "every student in every school should have the opportunity to learn computer science" [13]. While some of these efforts focus on computer science, at least in name, the efforts are relevant to computing in general. In a comprehensive study focusing on the state of Georgia, Guzdial et al. [26] examined how computing experiences in middle and high school influenced students choices to pursue computing in college.

Beyond the traditional high school-to-college path [21], it is important to consider other entry-points or pathways into an IT degree. These include transfer from two-year or three-year technical schools or community colleges; transfer into IT from another major; transfers from industry-university articulation agreements; returning to school from industry, for example to change careers; and transfers due to other life experiences.

It should also be noted that educational pathways into and through IT may not include a traditional bachelor's degree IT program at all. Students can obtain associate degrees in IT from community colleges or technical schools, or certificates from professional code schools or training companies. Some students pursue self-study or use online resources or MOOCs to teach themselves IT, and may obtain industry certifications to demonstrate their skills.

5.2.2 Australian Educational Pathways

In Australia, the majority of students enter universities directly after their successful completion of high school with a national tertiary entrance ranking (NTER) score. If their NTER score is not high enough, and they know they wish to study IT, they may undertake TAFE qualifications, such as Certificate II, III and IV in IT, which then lead into the second or third year of the IT degree. However, there are people who do not wish to enter university straight from school, and may take a couple of years working in industry, or travelling and then come back as mature age students. Depending on their industry work, these students may receive recognition of prior learning (rpl) and simply take the remaining courses to complete their program. Finally, there are students who select other programs, typically Software Engineering or Computer Science, and may not do well and transfer across to the IT Program. These students are typically those who have very diverse backgrounds, possibly international students, who require a successful outcome for their degree program, regardless of the discipline.

Literature about pathways and success or otherwise is available on the Office of Learning and Teaching (OLT) website [52] where many federally funded projects have been undertaken. In one project report, McLaughlin et al summarize by stating that, "Higher education must become more accessible, flexible and equitable to underrepresented groups. Increasing the diversity of the student cohort is … central to ensuring individual, community and social well-being" [47]. In another final project report, Partridge et al. [54] report that educators have acknowledged the importance of designing approaches to education that are responsive to the rapid and ongoing technological change of the evolving information age and developing dynamic curricula that accommodate the demands of an increasingly broad and diverse employment landscape. Continuing, "Change has been recognized as critical for meeting current and future needs for employment in the profession and for providing a diverse supply of graduates with the attributes required for information work in the rapidly changing twenty-first century". For managing such rapid change, it is essential to consider student and tertiary education considerations, as well as industry workforce planning and future employability [27].

In Australia, many pathways and programs in IT exist, ranging from publicly funded TAFE (Tertiary and Further Education)

Colleges to polytechnics to universities that provide IT degree programs. There are also many private providers of IT such as http://www.it-pathways.com/ and several online providers. Open Universities Australia (OUA) offers IT programs and many universities offer online courses into OUA as well as providing their own online courses and programs and many combinations of blended learning to deliver their IT programs.

5.2.3 Educational Pathways in China

The development of IT-related undergraduate education has been a boom in China. Integrating the analysis and ideas of ACM-IEEE in the CC2005 document [11, 63], the Ministry of Education has encouraged universities to develop a variety of directions under the name "Computer Science and Technology". A new pyramid model of computing education was developed that identified three basic directions for training the nation's high tech workforce: science-oriented (computer science), engineering-oriented (computer engineering and software engineering) and technology-oriented (information technology), with the smallest talent pool at the top, and the largest talent pool at the bottom [65]. By the end of 2012, China had doubled the number of colleges and universities to 2,409, most of which have established their own IT institutions [59]. As a result, the IT major has become the most popular major in terms of total enrollment. For example, in the year of 2010, the total enrollment for all engineering majors was 1.172 million; IT majors alone accounted for as high as 28% [66].

Another special pathway provided by IT training companies exists. The Ministry of Information Industry, now renamed as the "Ministry of Industry and Information Technology" (MIIT), launched the "national information technology talent cultivation project" in 2004. It aimed to optimize integration degree education, professional qualification, technical level and high and new technical training, and other various kinds of education training resources. It did this through the guidance of industry, government, to promote the socialization of education and training by opening up a new way of education and training. IT personnel innovation ability construction, reform the contents, methods and mechanisms of education training, deepening the reform of the management system of the IT talent, cultivate a large number of in-line with the industry development needs the innovative talents. The Education and Test Center of MIIT is responsible for the specific certification issues. There are more than 70 organizations and nearly 200 exam training bases, training about 700,000 – 1,000,000 IT professionals each year [48]. This is a very important IT talent resource.

5.2.4 Canadian Educational Pathways

In Canada the traditional high school pathway into university or college IT, computer science, MIS programs is still the most popular path, with approximately 58,000 students enrolled in these programs each year and with approximately 13,000 graduates. This indicates many students are taking classes either supplementing current knowledge and not necessarily to complete a diploma or university program. Only a relatively small percent of post-secondary students is specific to IT and the computing sciences. The total number of post-secondary students enrolled in the 2012/13 school year in Canada 2.023,191; (i.e., college enrollment 739,959; university enrollment 1,283,229) [61]. In the area of mathematics, computer and information sciences programs, 58,230 students enrolled (i.e., college enrollment 19734; university enrollment 38,493). Total graduates were 13,092 in the area of mathematics, computer and information sciences programs (i.e., college graduates 5787; university graduates 7308).

Today, more arrangements that are cooperative are occurring each year between university four-year IT programs and college two-year IT programs for transfer credits from the two-year diploma programs to the four-year university programs. In addition, there are now many 'university colleges' that are accredited to provide degrees, with approval from the accreditation body, Universities Canada (formerly The Association of Colleges and Universities in Canada, AUCC) [53]. IT and computer science program accreditation is handled by the Accreditation Council of CIPS, Canada's Association of IT Professionals [9].

An advisory committee made up of industry leaders from the region the institution serves guides most IT programs. For generalist positions such as IT support technician some institutions look to Canada's Information and Communications Technology Council's competency profiles to guide curriculum development. Others rely on their advisory committees and the experience and knowledge of their faculty. Current technical skills are only one part of a good IT graduate and institutions refer to organizations like the Canadian Information Processing Society (CIPS) and their body of knowledge and professionalism and ethics materials to inform the balance of a program's outcomes. Many also collaborate with their business programs to provide the critical business knowledge seen by some as a requirement for all IT workers. "We estimate that by 2016 approximately 106,000 ICT jobs will need to be filled in Canada with demand for critical jobs far exceeding the supply. This figure will be further compounded if we account for the new emerging ICT sectors" [2].

5.3 Future of IT

5.3.1 Surveys and Indicators

The data from the industry survey indicate clearly that project management, cybersecurity, and soft skills are among the top skills needed in the next decade. These skills are also important today where project management is an expected talent in the IT industry and where industry expects cybercrime losses to exceed $120 billion USD by 2017 [16]. Industry considers soft skills to be equally as important as technical skills when making hiring decisions.

What do we consider soft skills? They are "desirable qualities for certain forms of employment that do not depend on acquired knowledge: they include common sense, the ability to deal with people, and a positive flexible attitude" [19]. When hiring either IT graduates or experienced IT professionals, employers will often choose a candidate with excellent interpersonal skills who lacks certain technical skill sets over a more technically strong person lacking soft skills. They find they can easily train them in these technical skills in a seminar or on the job. People normally learn interpersonal skills away from a classroom; it is part of one's upbringing or interacting in social situations.

The new strategy for the internet of things (IoT) supporting the development of the most dynamic and agile IoT ecosystem and industry in the world, could really transform people's lives, drive growth, create employment and address societal challenges [35]. According to estimates, nearly five billion things will interconnect by 2015, reaching 25 billion by 2020, helping users save energy, reduce traffic jams, increase comfort, and get better healthcare and increased independence. IoT will not only allow companies to change their traditional business models through new services, but will also help combine the benefits of selling products with value-added digital service. According to the strategy there are selected current prominent areas of the internet of things: research cluster;

innovation ecosystems; IoT standardization; policy issues (trust, security, liability, privacy); smart living environments for ageing well (e.g., smart house); smart farming and food security; wearables; smart cities; smart mobility (smart transport/smart vehicles/connected cars); smart environment (smart water management); smart manufacturing [35].

We expect the cloud to be a standard fixture for the mid-2020s. Cloud computing is a technology that combines the internet, web browsers, and rich applications into one. The National Institute of Standards and Technology in the United States suggests that "cloud computing is a model for enabling convenient, on-demand network access to a shared pool of configurable resources (e.g. networks, servers, storage, applications and services) that can rapidly be provisioned and released with minimal management effort or service provider interaction [50]. To a cloud-based service, a provider uses a cluster of servers to offload processing provide or storage for a user. The future of the cloud is more interesting than discussing its current merits and failures. With each development, there will be cloud companies that will develop a distinct segment. According to Dinh et al. [20], a flood of IT innovations such as data center virtualization, optimization and automation, while greatly beneficial, have also brought diverse solutions and physical and virtual challenges to today's data center infrastructure.

The best response to these new challenges is effective IT management. Effective IT management requires a vendor-independent platform and centralized data center management capability. Enterprise Management Associates (EMA) explores a pragmatic view of data center management in order to deliver the best practices in real-world data centers for overarching management solutions. This will enable interoperability of managed entities across physical and virtual boundaries and help IT to control costs and manage diverse, complex technology environments while achieving core objectives for availability and security. Mims presents the idea of forgetting 'the Cloud'; 'the Fog' is tech's future. He also declares that cloud advocates are fond of declaring that 100% of computing will someday reside in the cloud. Getting data into and out of the cloud is harder than most engineers (or at least their managers) often are willing to admit. The problem is bandwidth. If you are a company simply seeking to save the cost and headache of storing data yourself, the cloud is great as long as all you need to do is transfer data back and forth via high-speed wiring [49].

5.3.2 Information Resources

The issue is that there are too many sources of information. It will be a challenge to weed through irrelevant information and hype to distinguish true industry trends. Determining which is hype and which is not, should rely on the persistence of an emerging or disruptive technology; the number of years it persists will determine if it truly should be incorporated into the curricula development processes. In a way, the speed at which the curricula development takes will lend itself to this filtering process. In addition, the research that supports the insertion of new knowledge areas will rely on materials spanning multiple years that in itself then will ignore short-term hype or buzz phrases.

The length of time in existence and sustainability within the IT industry can also filter IT practitioner (member) organizations. These practitioner associations publish survey results, white papers, position papers and often-monthly journals, newsletters and internal publications that are a vast resource for materials. The Federation of Enterprise Architecture Professional Organizations (FEAPO) lists some such long-lived organizations (Appendix D).

Current conference proceedings and outcome documents are a great resource for current industry directions and trends. In this category, worldwide organizations will provide a perspective that professionals should watch closely. Organizations connected to the UN have a unique perspective since rather than having specific countries interests in mind, they have the global interests in mind. Table 5.1 shows some examples of such proceedings. Obviously, books are still a resource that we should not overlook. Some examples of books that discuss and provide opinion and research for the future of IT include "Second Machine Age: Work, Progress and Prosperity in a Time of Brilliant Technologies" [6] and "The Shift: The Future work is already here" [24].

Table 5.1 Examples of UN-related organizations

WCC 2015, Opening our Future Together	http://www.wcc-2015.org/
World Summit on the Information Society	http://groups.itu.int/wsis-forum2012/Highlights/OutcomeDocument.aspx http://www.itu.int/net4/wsis/forum/2015/
UN Sustainable Goals	https://sustainabledevelopment.un.org/focussdgs.html
38th International Conference on Software Engineering	http://2016.icse.cs.txstate.edu/

Educational program delivery (i.e., secondary, post-secondary and graduate) is also an obvious source of material to follow the changes occurring in the IT industry. Most programs have regular input from industry advisory committee or boards to ensure they align with industry needs. Moreover, many accreditation bodies exist which again regularly evaluate education program content and delivery (i.e., learning outcomes). Also in this similar area there is professional development delivery (post-academic, non-credit programs) specific to an industry or IT domain that often fill gaps for emerging areas of specialization the industry is looking for. It is not feasible to list the plethora of programs available today; one could be easily research them to determine trends occurring in the IT domain.

Another source that again is not reasonable to list here is the technology vendor conferences, tradeshows and expos. Vendor presentations are often aimed and discussing innovations and new products providing an endless supply of information.

Table 5.2. Examples of IT-related websites

Forbes	http://www.forbes.com/
Forrester	https://www.forrester.com/home/
Facebook	https://www.facebook.com/OpenAcademyProgram
Gartner	http://www.gartner.com/technology/home.jsp
IT World	http://www.itworldcanada.com/
LinkedIn	https://www.linkedin.com/
Twitter	https://twitter.com/search?q=TechnologyReview&src=tyah
Australia's skills shortage reports	http://www.businessinsider.com.au/australia-needs-another-100000-tech-workers-as-the-economy-is-hit-with-another-wave-of-digital-disruption-2015-6 http://www.hcamag.com/hr-news/popular-culture--the-root-of-australias-serious-skills-shortage-201687.aspx
Canadian Market Outlook	http://www.digcompass.ca/labour-market-outlook-2015-2019foward/

Table 5.2 shows examples of general news articles and posts on the multitude of websites now available related to IT.

6. SUMMARY

Based on the research findings, the working group has arrived at the several conclusions. With regard to the meaning of IT, the research shows that many meanings of IT exist depending on academia, industry, geographic location. Additionally, the content of an academic degree in a particular country often reflects the needs of the industry in that area. Indeed, information technology is a communication and information platform that is ubiquitous that moved from the techies to the masses. Therefore, it is important to prepare IT students to work with diverse applications and professions because IT is an enabler; it promises to generate greater growth in the future.

With respect to curricular IT frameworks, there is agreement between industry and academia on science requirements and highly close agreement on math requirements. Statistics is a top subject choice for math that is necessary in all IT degree programs. Knowledge areas of importance showed various agreements and disagreements, but overall the data show a general positive agreement. The structure of IT programs varies by type of institution and geographic location. There were significant differences between US and non-US IT degree programs regarding the IT technical component, where non-US IT programs were more robust in their technical components that provided a normal pathway to graduate study. The top knowledge areas for which industry and academia reached agreement were cybersecurity and information management.

Regarding IT pathways to a bachelor's degree in IT, the research showed that US IT programs provided more transfers from many sources, but even more transfers occurred from two-year and three-year technical programs. We found that demand, IT intensity, and program size correlate differently with participation of transfers. In non-US countries, transfers to baccalaureate programs were few due to very limited pathways and conformity to local regulations.

The future of IT remains fluid as expected. Notwithstanding, it was intensely clear from the research that soft (people) skills are as important as technical skills and that project management is an important professional skill. IT university enrollments must keep up with job demands as the IT industry changes. When designing undergraduate programs, universities would be wise to consider curricular IT reports from professional organizations and use predictor data from IT trackers such as Forbes and Gartner organizations so their programs are as futuristic as possible in an ever-changing IT world.

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APPENDIX
A. FACULTY SURVEY
A.1 Faculty Survey Items

F1	Country in which the main campus of my institution of higher learning exists
F2	Names of the department or academic unit
F3	Names of the computing degree programs in my department
F4	Total number of graduates from my undergraduate information technology (or closely related) degree program(s) over the past year is approximately: less than 100 students, Between 100 and 300 students, Between 300 and 500 students, Over 500 students
F5	Percent of graduating students who continue their studies in graduate school: Less than 1%, Between 1% and 10%, Between 10% and 20%, Over 20%
F6	Areas of mathematics necessary to produce a competent IT graduate in the mid-2020s: Statistics, Discrete mathematics, Probability, Linear algebra, Applied calculus, Business mathematics, Finite mathematics, Other
F7	Areas of mathematics currently required in the program to produce a competent IT graduate in the mid-2020: Discrete mathematics, Statistics, Applied calculus, Linear algebra, Finite mathematics, Business mathematics, Other
F8	Number of math courses currently required in the program to produce a competent IT graduate: 0, 1, 2, 3, 4, 5, 6, 7, 8 or more
F9	Science subjects necessary to produce a competent IT graduate in the mid-2020s: None (except Gen Ed), Physics, Biology, Chemistry, Geology, Other
F10	Science subjects currently required in the program to produce a competent IT graduate in the mid-2020: None (except Gen Ed), Physics, Application Domain, Chemistry, Biology, Geology, Other
F11	Number of science subjects currently required in the program to produce a competent IT graduate: 0, 1, 2, 3, 4, 5 or more
F12	A credit-bearing internship experience at the undergraduate information technology program: Required, Optional, Not Offered
F13	The 8 most important areas you believe will be essential or fundamental for IT graduates to know in in the mid-2020s: Big Data, Cloud Computing, Cybersecurity: Digital Forensics and Response, Green Computing, Human Computer Interaction, Information Assurance and Cybersecurity, Information Management, Internet of Things, Integrative Programming Technologies, Networking, System Administration and Maintenance, System Integration and Architecture, Social and Professional Issues, Programming, Platform Technologies, Virtualization, Web Systems and Technologies, Other.
F14	The technical (IT) component of the full degree program is approximately for the undergraduate information technology (or closely related) degree program: Less than 30% of the total program, Between 30% and 50% of the total program, Between 50% and 65% of the total program, Over 65% of the total program
F15	The principal source of significant external student transfers to the information technology (or closely related) program: Few external transfer students, Transfers from two or three-year, Transfers due to life experiences, Industry-university articulation, Not sure/Not Available

A.2 Faculty Survey Results

1. The country in which the main campus of my institution of higher learning exists is: (589 responses)

United States	205	34.8%	Argentina	3	0.5%
Canada	47	8.0%	Colombia	3	"
Australia	42	7.1%	France	3	"
Brazil	42	7.1%	Jordan	3	"
Germany	26	4.4%	Poland	3	"
Spain	22	3.7%	Bangladesh	2	0.3%
United Kingdom	17	2.9%	Cyprus	2	"
China	14	2.4%	Finland	2	"
Austria	13	2.2%	Japan	2	"
Belgium	13	2.2%	Macedonia	2	"
Greece	11	1.9%	Sri lanka	2	"
Italy	11	1.9%	Taiwan	2	"
Portugal	11	1.9%	Albania	1	0.2%
India	10	1.7%	Bahrain	1	"
South Africa	9	1.5%	Croatia	1	"
Mexico	8	1.4%	El Salvador	1	"
Bulgaria	6	1.0%	Estonia	1	"
Chile	6	"	Kenya	1	"
Denmark	5	0.8%	Latvia	1	"
Ireland	5	"	Netherlands	1	"
Malaysia	5	"	Nigeria	1	"
New Zealand	4	0.7%	Norway	1	"
Philippines	4	"	Pakistan	1	"
Romania	4	"	Singapore	1	"
Sweden	4	"			
Switzerland	4	"			

2. The name of the department or academic unit (e.g., information technology, informatics, etc.) in which I have an appointment is: (A bewildering variety)

3. The names of the computing degree programs in my department are:
(Also a bewildering variety, but of 589 responses)

at least one undergraduate program	581	98.6%
at least one graduate program	458	77.8%

4. The total number of graduates from my undergraduate information technology (or closely related) degree program(s) over the past year is approximately: (591 responses)

Less than 100 students	315	53.3%
Between 100 and 300 students	200	33.8%
Between 300 and 500 students	47	8.0%
Over 500 students	29	4.9%

5. The percent of graduating students from my undergraduate information technology (or closely related) degree program who continue their studies in graduate school is approximately: (591 responses)

Less than 1%	49	8.3%
Between 1% and 10%	270	45.7%
Between 10% and 20%	134	22.7%
Over 20%	138	23.4%

6. For a strong and rigorous undergraduate degree program in information technology, indicate the areas of mathematics you believe are necessary to produce a competent IT graduate in the mid-2020s. Check all that apply. (542 responses)

Statistics	447	82.5%
Discrete mathematics	440	81.2%
Probability	363	67.0%
Linear algebra	275	50.7%
Applied calculus	266	49.1%
Business mathematics	154	28.4%
Finite mathematics	149	27.5%
Other	41	7.6%

7. Which areas of mathematics does your program currently require to produce a competent IT graduate? (530 responses)

Discrete mathematics	395	74.5%
Statistics	374	70.6%
Applied calculus	318	60.0%
Linear algebra	288	54.3%
Probability	286	54.0%
Finite mathematics	110	20.8%
Business mathematics	82	15.5%
Other	54	10.2%

8. How many math courses does your program currently require to produce a competent IT graduate? (541 responses)

0	24	4.4%
1	66	12.2%
2	98	18.1%
3	125	23.1%
4	135	25.0%
5	30	5.5%
6	39	7.2%
7	24	4.4%
8 or more	11	2.0%

9. For a strong and rigorous undergraduate degree program in information technology, indicate the science subjects you believe are necessary to produce a competent IT graduate in the mid-2020s. Check all that apply. (535 responses)

None (except General Education)	270	50.5%
Physics	219	40.9%
Other	74	13.8%
Biology	68	12.7%
Chemistry	38	7.1%
Geology	18	3.4%

10. Which science subjects does your program currently require to produce a competent IT graduate? (546 responses)

None (except Gen Ed)	243	44.5%
Physics	171	31.3%
Application Domain	111	20.3%
Other	69	12.6%
Chemistry	55	10.1%
Biology	27	4.9%
Geology	10	1.8%

11. How many science courses does your program currently require to produce a competent IT graduate? (533 responses)

0	124	23.3%
1	110	20.6%
2	149	28.0%
3	80	15.0%
4	58	10.9%
5 or more	12	2.3%

12. For the undergraduate information technology program at my institution, a credit-bearing internship experience is: (541 respondents)

Required	173	32.0%
Optional	273	50.5%
Not Offered	95	17.6%

13. Consider the following list of knowledge areas for information technology as developed by the IT2017 Task Group. Indicate the 8 most important areas you believe will be essential or fundamental for IT graduates to know in the mid-2020s. (541 respondents: Top 8 in bold font)

Big Data	353	65.2%
Cloud Computing	342	63.2%
Cybersecurity: Digital Forensics and Response	271	50.1%
Green Computing	79	14.6%
Human Computer Interaction	328	60.6%
Information Assurance and Cybersecurity	310	57.3%
Information Management	275	50.8%
Internet of Things	182	33.6%
Integrative Programming Technologies	130	24.0%
Networking	368	68.0%
System Administration and Maintenance	181	33.5%
System Integration and Architecture	233	43.1%
Social and Professional Issues	205	37.9%
Programming	443	81.9%
Platform Technologies	86	15.9%
Virtualization	176	32.5%
Web Systems and Technologies	405	74.9%
Other	86	15.9%

14. For the undergraduate information technology (or closely related) degree program at your institution, the technical (IT) component of the full degree program is approximately: (541 responses)

Less than 30% of the total program	75	13.9%
Between 30% and 50% of the total program	150	27.7%
Between 50% and 65% of the total program	179	33.1%
Over 65% of the total program	137	25.3%

15. Excluding first-time admission to an undergraduate program, indicate the principal source of significant external student transfers to the information technology (or closely related) program at your institution. (537 responses)

Few external transfer students	187	34.8%
Transfers from two or three-year	177	33.0%
Transfers due to life experiences	43	8.0%
Industry-university articulation	18	3.4%
Not sure/Not Available	112	20.9%

B. INDUSTRY SURVEY

B.1 Industry Survey Items

I1	Country in which the mail location of my company exists is ..
I2	Name of the IT department or unit in which I work is ...
I3	The most recent total number of employees from my IT department is approximately: Less than 10 employees, Between 10 and 30 employees, Between 30 and 50 employees, Between 50 and 100 employees, Over 100 employees.
I4	Areas of mathematics necessary to produce a competent IT graduate in the mid-2020s: Statistics, Financial modeling and budgeting, Business mathematics/calculus, Probability, Linear algebra, Discrete mathematics, Applied calculus, Finite mathematics, Other.
I5	Science subjects necessary to produce a competent IT graduate in the mid-2020s: Physics, Chemistry, Biology, Geology, Other
I6	The 8 MOST IMPORTANT AREAS you believe will be essential or fundamental for IT graduates to know in in the mid-2020s: Big Data, Cloud Computing, Cybersecurity: Digital Forensics and Response, Green Computing, Human Computer Interaction, Information Assurance and Cybersecurity, Information Management, Internet of Things, Integrative Programming Technologies, Networking, System Administration and Maintenance, System Integration and Architecture, Social and Professional Issues, Programming, Platform Technologies, Virtualization, Web Systems and Technologies, Other.
I7	The top six skill sets will require of new IT graduates in the mid-2020s: Project management, Cloud Computing, Business analytics, Data analytics, Database administration and architecture, Information (cyber) security, Quality assurance, PC/desktop support, Networking, Programming, Help desk support, Soft skills, Rudiments of finance, Other.

B2. Industry Survey Results

1. The Country in which the mail location of my company exists is: (of 91 responses)

United States	90	98.9%
Nigeria	1	1.1%

2. The name of the IT department or unit in which I work is:
(A bewildering variety)

3. The most recent total number of employees from my IT department is approximately: (91 responses)

Less than 10 employees	41	45.1%
Between 10 and 30 employees	18	19.8%
Between 30 and 50 employees	5	5.5%
Between 50 and 100 employees	7	7.7%
Over 100 employees	20	22.0%

4. For a strong and rigorous undergraduate degree program in information technology, indicate the areas of mathematics you believe are necessary to produce a competent IT graduate in the mid-2020s. Check all that apply. (91 responses)

Statistics	68	74.7%
Financial modeling and budgeting	62	68.1%
Business mathematics/calculus	61	67.0%
Probability	46	50.5%
Linear algebra	26	28.6%
Discrete mathematics	25	27.5%
Applied calculus	20	22.0%
Finite mathematics	18	19.8%
Other	10	11.0%

5. For a strong and rigorous undergraduate degree program in information technology, indicate the science subjects you believe are necessary to produce a competent IT graduate in the mid- 2020s. Check all that apply. (91 responses)

Physics	51	56.0%
Other	41	45.1%
Chemistry	23	25.3%
Biology	14	15.4%
Geology	3	3.3%

6. Consider the following list of knowledge areas for information technology as developed by the IT2017 Task Group. Indicate the eight most important areas you believe will be essential or fundamental for IT graduates to know in the mid-2020s. (91 responses, **Top eight in bold)**

Big Data	44	48.4%
Cloud Computing	59	64.8%
Cybersecurity and Digital Forensics	68	74.7%
Green Computing	18	19.8%
Human Computer Interaction	41	45.1%
Information Assurance and Security	**54**	**59.3%**
Information Management	53	58.2%
Internet of Things	34	37.4%
Integrative Programming Technologies	26	28.6%
Networking	50	54.9%
System Administration and Maintenance	33	36.3%
System Integration and Architecture	55	60.4%
Social and Professional Issues	45	49.5%
Programming	45	49.5%
Platform Technologies	20	22.0%
Virtualization	55	60.4%
Web Systems and Technologies	58	63.7%
Other	6	6.6%

7. Indicate the top six skill sets you believe your organization will require of new IT graduates in the mid-2020s. (91 responses, **Top six in bold**)

Project management	**71**	**78.0%**
Cloud Computing	39	42.9%
Business analytics	**54**	**59.3%**
Data analytics	**45**	**49.5%**
Database administration and architecture	**47**	**51.6%**
Information (cyber) security	**67**	**73.6%**
Quality assurance	22	24.2%
PC/desktop support	21	23.1%
Networking	41	45.1%
Programming	37	40.7%
Helpdesk support	23	25.3%
Soft skills	**59**	**64.8%**
Rudiments of finance	21	23.1%
Other	10	11.0%

C. FACULTY SURVEY DATA ON SOURCES OF EXTERNAL TRANSFER STUDENTS

Table C.1: Transfer into programs by program size, for demanding (1st row) and all (2nd row) programs

	Number of graduates in 2014-2015			
Transfer Source	**<= 100**	**100-300**	**300-500**	**> 500**
No significant number of external transfer students	28/52% 92/41%	17/53% 63/44%	8/80% 21/53%	5/56% 11/52%
Transfers from two-year or three-year technical institutes or community colleges	16/30% 95/43%	8/25% 57/40%	2/20% 17/43%	3/33% 8/38%
External transfers due to life experiences	5/9% 25/11%	4/13% 15/11%	0 2/5%	0 1/5%
Industry-university articulation agreements	5/9% 10/5%	3/9% 7/5%	0 0	1/11% 1/5%

Table C.2: Transfer into programs by program technical content for demanding (1st row, red) and all (2nd row, blue) programs

	% of total degree program that is technical			
Transfer source	**< 30%**	**30-50%**	**50-65%**	**> 65%**
No significant number of external transfer students	28/ 44%	44/ 35%	36/54% 55/41%	22/58% 60/59%
Transfers from two-year or three-year technical institutes or community colleges	26/ 41%	66/ 52%	21/31% 58/43%	8/21% 27/26%
External transfers due to life experiences	8/ 13%	10/ 8%	6/9% 15/11%	3/8% 10/10%
Industry-university articulation agreements	1/ 2%	6/ 5%	4/6% 6/4%	5/13% 5/5%

D. MEMBER ORGANIZATIONS FROM FEAPO

Association for Computing Machinery (ACM) https://www.acm.org/
Association of Enterprise Architects (AEA) https://www.globalaea.org/
Association for Enterprise Information http://www.afei.org/
Association of IT Professionals (AITP) https://www.aitp.org/
ASIS&T - Association for Information Science & Technology https://www.asist.org
Australian Computer Society (ACS) https://www.acs.org.au/
British Computer Society (BCS) http://www.bcs.org/
Business Architecture Guild http://www.businessarchitectureguild.org/
Canadian Information Processing Society (CIPS) http://www.cips.ca/
Center for the Advancement of the Enterprise Architecture Profession (CAEAP) http://www.caeap.org/
Data Management Association (DAMA) http://www.dama.org/
DGI - Data Governance Institute www.datagovernance.com
Federation of EA Professional Organizations (FEAPO) http://feapo.org/
The Global IT Community Association www.gitca.org
IEEE Computer Society http://www.computer.org/web/csdl/
The International Federation for Information Processing , IFIP http://www.ifip.org/
IFIP/ International Professional Practice Partnership, IP3 http://ipthree.org/
Information Architecture Institute http://iainstitute.org/
Information Systems Audit and Control Association (ISACA) www.isaca.org
International Information System Security Certification Consortium $(ISC)^2$ https://www.isc2.org/
International Association of Software Architects (IASA) http://iasaglobal.org/
International Council on Systems Engineering (INCOSE) www.**incose**.org/
International Institute of Business Analysis http://www.iiba.org/
Institute of Information Technology Professionals New Zealand
Institute for EA Development http://www.enterprise-architecture.info/
The National Association of State Chief Information Officers
Netherlands Architecture Forum http://www.naf.nl/
The Network Professional Association http://www.npa.org/
Object Management Group http://www.omg.org/
SOA Institute http://www.soainstitute.org/
Software Engineering Institute (SEI) http://www.sei.cmu.edu/
Society for Information Management https://www.simnet.org/