Lappeenranta University of Technology
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PERCCOM Master Program

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SUSTAINABLE COMPUTER SCIENCE EDUCATION

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- Master of Science in Complex Systems Engineering (University of Lorraine)
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ABSTRACT

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As the world becomes more technologically advanced and economies become globalized, computer science evolution has become faster than ever before. With this evolution and globalization come the need for sustainable university curricula that adequately prepare graduates for life in the industry. Additionally, behavioural skills or "soft" skills have become just as important as technical abilities and knowledge or "hard" skills. The objective of this study was to investigate the current skill gap that exists between computer science university graduates and actual industry needs as well as the sustainability of current computer science university curricula by conducting a systematic literature review of existing publications on the subject as well as a survey of recently graduated computer science students and their work supervisors. A quantitative study was carried out with respondents from six countries, majorly Finland, 31 of the responses came from recently graduated computer science professionals and 18 from their employers. The observed trends suggest that a skill gap really does exist particularly with "soft" skills and that many companies are forced to provide additional training to newly graduated employees if they are to be successful at their jobs.

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LIST OF SYMBOLS AND ABBREVIATIONS

ACM	Association for Computing Machinery
AL	Algorithms and Complexity
AR	Architecture and Organization
CN	Computational Science
CS	Computer Science
CS2013	Computer Science Curricula 2013
DS	Discrete Structures
GV	Graphics and Visualization
HCI	Human-Computer Interaction
IAS	Information Assurance and Security
IEEE	Institute of Electrical and Electronics Engineers
IM	Information Management
IS	Information Systems
IT	Information Technology
NC	Network and Communication
OS	Operating Systems
PBD	Platform-Based Development
PD	Parallel and Distributed Computing
PERCCOM	Pervasive Computing & Communications for Sustainable Development
PL	Programming Languages
RO	Research Objective
RQ	Research Question
SDF	Software Development Fundamentals
SE	Software Engineering
SF	Systems Fundamentals
SP	Social Issues and Professional Practice

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1 INTRODUCTION

How well do new computer science graduates fit into their professional roles? How well prepared are they by their degree programs on what to expect in these new roles? Are graduates equipped to successfully integrate into working life? In what areas do they struggle? These are questions that are relevant to today's fast evolving computing industry as producing computer science graduates who are well prepared for roles within the industry, although a goal, could be challenging for most CS university programs as emphasis is usually placed on imparting as much academic knowledge as possible within the limited timeframe of study programs. It has been noted that graduates who join the workforce directly from university often have to be brought up to speed in order to make productive contributions in their new roles (Begel and Simon, 2008).

There has been a lot of research in recent years on the need to reduce the current skill gap between university education and the demands of the labour market (Hernández-March et al, 2009). Microsoft for instance, has an orientation process known as 'onboarding' when new recruits adjust to become efficient and productive members of the company (Begel and Simon, 2008).

Perhaps the problem stems from the fact that computer science development began at a time when unlike today, it was a student's first introduction to computing and the software that have become so commonplace today had not yet been written (Patterson, 2006). Being a rapidly evolving field, it is essential that a flexible structure be adopted due to the continuous and ever changing nature of the discipline. It is however a delicate thing as new technologies do not always survive in the long run, and making changes based on such short-lived technologies would likely result in a fragmented and unfocused curriculum (McDonald, 1999). Sustainability is therefore a major concern in the design of a good curriculum as the curriculum must be adaptable and easily modifiable based on new trends. Another side to the issue of sustainability is that university curricula should include courses that sensitize CS students to social and environmental impact of computer use and disposal as well as to consider the environmental impacts of design and

implementation methods such as resource consumption and organizational policies in areas such as networks, databases, and algorithms

1.1 Aims and Objectives

The aim of this study is to investigate the gap that may exist between computer science graduate abilities and industry expectations, in other words, the sustainability or lack thereof of CS curricula. The following objectives were defined to this end:

First, an investigation of the existing skill gap in CS graduates will be carried out prompting a look at the current CS curricula development practises which will in turn raise questions like how universities prepare their CS curriculum, how often these are updated and what factors affect such updates.

Two research questions have been coined from this research objective. The first research question is to determine how relevant graduate skills are to current industry needs; and secondly, to examine how much additional training is provided by companies to new hires.

The second objective is to analyse the difference in expectations between universities, students and the industry. This will reveal what struggles CS graduates face in the transition from classroom to professional working life and particularly how much additional training companies need to provide to CS graduates to enable them perform their jobs effectively.

1.2 Structure of the Thesis

This thesis is divided into five chapters including the introduction and conclusion.

- The first chapter is the introduction which examines the background of the research (problem statement), its aims and objectives and provides a summary of the thesis structure.
- Chapter 2 provides a systematic review of existing research relating to CS curricula, its sustainability and the perceived skill gap in CS graduates. It contains five subchapters: chapter 2.1 provides a brief look into the evolution of computer science as a discipline as well as its trend amongst students over the years. The sub-chapter further reviews the existing literature on CS curriculum development and its practices. Chapter 2.2 examines the differences in expectations between universities, students and the CS industry, while chapter 2.3 takes a brief look at sustainability of the CS curricula and development process. Finally, chapters 2.4 and 2.5 briefly review the general perception of the skill gap and conclude the chapter respectively.
- Chapter 3, the methodology chapter, extensively discusses the methods and guidelines followed in the execution of this thesis. It presents and justifies the chosen statistical method, describing the measurement of attitudes and the design and administration of the survey questionnaires (data collection) and their analyses.
- The results of the research are presented according to the defined research objectives in chapter 4 as well as a discussion of the findings and how they fit in with existing works in this topic area.
- Finally, chapter 5 concludes the thesis with practical recommendations for the future and further research on the topic. Limitations encountered in the course of the research are also explained.

1.3 Limitations of the Study

A major limitation of this study was the small sample size due to limited resources available to the researcher. The collected responses (31 graduates and 18 employers) are relatively few making it a challenge to validate the study's statistical relevance.

Computer science is a broad field that is taught in most countries, however, it would have been impossible to survey a significant number of countries in the few months it took to conduct this research. This research is therefore limited to a few European countries primarily. The conducted literature review is not representative of all CS graduates or global CS curricula development, however, the aim of the study which is to give a first picture of the existing skill gap amongst CS graduates as well as the importance of sustainable CS curricula and a significant variety of responses were collected so this aim was hopefully achieved.

2 LITERATURE REVIEW

A literature review is often conducted in academia as a means of identifying existing research relevant to a particular topic or area of interest and then evaluating and interpreting said research (Kitchenham, 2007).

This chapter will provide the context for the entire thesis by providing an in-depth look into existing research on CS curriculum development process, its history and current practices, the expectations of industry versus the preparation computer science graduates receive from universities (skill gap) as well as introducing the concept of sustainability in the curriculum development process by presenting discussions from a number of researchers in this topic area.

2.1 Computer Science Curriculum

According to Tucker and Wegner (1994), Computer science emerged as a distinct field of its own in the sixties due to the ever growing applications of computers, mainly focused on the theory, design, and implementation of algorithms for the manipulation of data and information hence aiding people in several forms of computation (Sahami et al., 2013). As with any such complex field though, creating a standard and suitable curriculum has been a challenge for computer science and this has been evidenced by a noticeable decrease in interest amongst students through the years.

Patterson (2006) believes that the reason for the observed decline in interest in computer science amongst students is as a result of CS curricula having become outdated and dull. He proposes that this trend could be reversed with a reinvigorated CS curriculum. Also, according to Carter (2006), statistics show that computer science is becoming less popular among students in the United States. With a continuously and rapidly evolving discipline like CS, it is quite easy for the curriculum to become fragmented and unfocused when new changes are constantly being made when new technologies emerge when in fact many of these emerging technologies are short-lived (McDonald, 1999).

The ACM and IEEE societies have sponsored efforts to create standard international guidelines for undergraduate programs in computer science since the late sixties and do so on a roughly ten-year cycle. The created curricula are regularly updated so as to keep them modern and relevant, which can be a challenge given the present rate of evolution of the computer science discipline resulting in a growing diversity of potentially relevant topics. To successfully manage this task, the ACM/IEEE CS2013 steering committee made sure to engage the CS education community in a dialog with the aim of developing a better understanding of local needs and new opportunities as well as to identify and possibly emulate both new and established computing curricula models. (Sahami et al., 2013). As part of this effort, the ACM/IEEE CS Curricula organize the computer science body of knowledge into knowledge areas that correspond to topical study areas in computing. In the CS2013, 18 KAs were defined with many coming directly from the previous 2001/2008 curriculum and a few others representing new areas that have become significant to CS education in the years since the last curriculum. IAS is one such example and is briefly defined below along with the other KAs that make up the 18 KAs of the CS2013.

A. Algorithms and Complexity (AL)

Algorithms are fundamental to computer science, its study gives the ability to understand and find solutions to a problem irrespective of the involved programming language or computer hardware. This knowledge area is essential to efficiently solving problems in computer science as it defines the central concepts and skills needed in the design, implementation and analysis of problem solving algorithms.

B. Architecture and Organization (AR)

AR builds on SF to develop a more thorough understanding of computer hardware which forms the basis for computing. It is essential for CS students to understand and appreciate a computer system’s functional components, their characteristics, performance, interactions, and the challenge of harnessing parallelism to sustain performance improvements.

C. Computational Science (CN)

CN falls under the field of applied computer science and hence combines computer simulation, scientific visualization, mathematical modelling, computer programming & data structures, networking, database design, symbolic computation, and high performance computing with various disciplines for the aim of applying them to the solution of problems across various disciplines.

D. Discrete Structures (DS)

Computer scientists rarely work primarily on DS, however, it is an essential basis for working on many other areas of CS. DS is comprised of important material from areas such as logic, set theory, graph theory, and probability theory. Graph theory concepts for instance, are applied in networks and operating systems. Given that discrete structures are a basis for many parts of CS, the boundary between it and many other areas of CS such as Intelligent Systems may not always be clearly discernible.

E. Graphics and Visual Computing (GV)

Cartoons and film special effects may be the first thing that come to mind when thinking about GV and would not be wrong. With GV visual communication is enabled through computation and addresses many issues such as file formats, hardware interfaces, and application program interfaces. GV is comprised of several interrelated fields: Fundamentals, Modelling, Rendering, Animation, Visualization, and Computational Geometry.

F. Human-Computer Interaction (HCI)

Like the name suggests, HCI is concerned with designing interactions between human activities and the computational systems that support them. Since it deals with both people and computer systems, HCI takes cultural, social, organizational, cognitive, and perceptual issues into account.

G. Information Assurance and Security (IAS)

This KA was only added to the Body of Knowledge in 2013 as a result of how much the world has come to rely on information technology and the critical role it plays in CS education. The intent behind IAS in the CS curriculum is to prepare equip students with necessary knowledge and skills to protect and defend information and

information systems by ensuring their availability, integrity, authentication, and confidentiality.

H. Information Management (IM)

Student needs to develop conceptual and physical data models, determine what IM methods and techniques are appropriate for a given problem, and have the ability to select and implement an appropriate IM solution that addresses relevant design concerns including scalability, accessibility and usability. IM is primarily concerned with the capture, digitization, representation, organization, transformation, and presentation of information; algorithms for efficient and effective access and updating of stored information, data modelling and abstraction, and physical file storage techniques.

I. Intelligent Systems (IS)

Intelligent systems provide solutions to problems that are difficult or impractical to solve with traditional methods. IS includes things like speech recognition, computer vision, and robotics as well as the architectures (such as Agents) needed to support them.

J. Networking and Communications (NC)

Networks have become a major part of computing today and dependency on them will likely increase in the future. It is therefore vital that CS students understand basic concepts of networking such as routing, forwarding and reliable delivery.

K. Operating Systems (OS)

An operating system defines an abstraction of hardware and manages resource sharing among the computer's users. Students are introduced to OS design and implementation with the KA structured to complement other KAs such as SF and IA from which several OS courses get their material.

L. Platform-based Development (PBD)

This is a new KA concerned with the design and development of software applications on specific software platforms. It takes into account platform-specific constraints.

M. Parallel and Distributed Computing (PD)

With the advent of multiprocessor computing, multi-core processors and distributed data centres, PD has become a core component of any standard computing curricula.

Parallel and distributed computing builds on foundations in many areas, including an understanding of fundamental systems concepts such as concurrency and parallel execution, consistency in state/memory manipulation, and latency.

N. Programming Languages (PL)

Programming languages are the medium through which programmers precisely describe concepts, formulate algorithms, and reason about solutions. Software developers must understand the programming models underlying different languages and make informed design choices in languages supporting multiple complementary approaches. Computer scientists will often need to learn new languages and programming constructs, and must understand the principles underlying how programming language features are defined, composed, and implemented.

O. Software Development Fundamentals (SDF)

To successfully study most topics in CS, a fluency in the process of software development is required. This KA brings together fundamental concepts and skills related to the software development process and therefore builds a foundation for other software-oriented knowledge areas, most notably Programming Languages, Algorithms and Complexity, and Software Engineering.

P. Software Engineering (SE)

SE is the discipline concerned with the application of theory, knowledge, and practice to effectively and efficiently create reliable software systems that satisfy defined requirements. It is applicable to small, medium, and large-scale systems and encompasses all phases of the lifecycle of a software system, such as requirements definition, analysis and specification; design; construction; verification and validation; deployment; and operation and maintenance.

Q. Systems Fundamentals (SF)

The Systems Fundamentals Knowledge Area is designed to present an integrative view of CS fundamental concepts in a simplified way, providing a common foundation for the different specialized areas.

R. Social Issues and Professional Issues (SP)

While technical issues are central to the computing curriculum, students must also be exposed to the larger societal context of computing to develop an understanding of the relevant social, ethical, legal and professional issues.

2.2 Sustainability in CS Curricula Development

Sustainability is a broad term that means different things to different situations. According to the Merriam-Webster English dictionary, to be sustainable means to be able to last or continue for a long time. Similarly, the United Nations defines it as "development that meets the needs of the present without compromising the ability of future generations to meet their own needs." For this, a balance of society, economy, and environment need to exist both presently and in the future. These definitions can be applied in many scenarios and as has become most popular in recent years, to the environment with the aim of ensuring that future generations will have sufficient resources not just to survive but to thrive.

In computer science curriculum development, the question is how to create and maintain curricula that are scalable such that they reflect the continuous changes in the discipline and teachers can successfully enact them (Fishman, 2003). Squire et al. (2003) argue that based on the uniqueness of every classroom, curricula should be developed with maximum flexibility in order to strengthen the ability of teachers to adapt curriculum materials based on their strengths and the needs of the students.

In educating computer science students, there are several facets of sustainability which should be considered. In the IEEE/ACM CS Curricula 2013, Sahami et al. (2013) present the following core areas which should be addressed by a sustainable CS curriculum:

- Training CS graduates to consider the environmental impacts of design and implementation decisions such as resource consumption and organizational policies in areas such as networks, databases, and algorithms.

- Taking an in-depth look at the social and environmental impacts of computer use and disposal

2.3 Skill Gap

Computer science students are not always prepared for the careers ahead of them upon graduating from university (Radermacher et al, 2014), in fact, Cranmer (2006) argues that skills needed by graduates to be successful in the labour market cannot be effectively developed in the classroom. Cranmer goes on to suggest that it would be more effective to expend resources on employer involvement in courses as this would better prepare graduates for the transition to the working industry. The speedy and constant change in technological advancements as well as the ongoing globalization of economies has led to organizations altering their internal structure and mode of operation which then leads to a change in the skills required from personnel and hence a skill gap amongst recent graduates (Hernández-March et al., 2009).

This skill gap is not limited to technical computer science skills such as programming but also to abilities such as communication and time management (Radermacher et al., 2014). A study conducted by Crebert et al. (2004), for instance, showed that while students valued traditional CS knowledge, teamwork, collaborative learning and responsibility emerged as the most important factors for successful transition into working life.

2.4 Summary

Understanding the existing skill gap amongst CS graduates and how university curricula can be made more sustainable to produce the highest calibre of CS professionals is essential for this study. This chapter has provided a brief look into existing research and general attitude towards sustainable computer science university curricula.

3 METHODOLOGY

In this chapter, the detailed implementation of the research methodology is presented. A methodological approach with a systematic review of existing academic works combined with quantitative survey methods as outlined by (Fink, 2013) was employed in order to accurately assess and compare attitudes as defined in the ROs. Chapter 3.3 begins by briefly exploring the issue of attitudes and how they can be measured. Following that, it sheds some light on the quantitative method including a breakdown of the survey design process, sampling, piloting, data collection and analysis.

3.1 Approach

According to Aliaga and Gunderson (2000), quantitative research is the collection of numerical data to be analysed through mathematical methods for the purpose of explaining a phenomenon. Quantitative methods make data more easily managed as it can be categorized and converted into a more measurable or mathematical form which allows a researcher to extract answers to specific questions from large and complex sets of data (Aliaga & Gunderson, 2000), therefore, attitudes and opinions of a group may be determined through the quantitative survey of a sample of that group (Creswell, 2013). In light of this, a self-administered quantitative questionnaire was applied in a longitudinal manner (data collected over a period of time). The survey was online and was accessible on any Internet enabled device.

As with any other form of survey, online surveys have some advantages and disadvantages but have become the preferred form of survey among surveyors (Fink, 2013). Some advantages (refer to Table 3.1 for more advantages and disadvantages) of online surveys include the real-time availability of the survey to anyone connected to the Internet and the ease with which data can be analysed especially when using tools specifically designed survey administration tools such as Webropol which was used in this study. The disadvantages include dependence on Internet availability.

Table 3.1 Benefits and drawbacks of online approach

Approach	**Benefits**	**Drawbacks**
Web-based *(italicized applies to non-solicited)*	• Turnaround time (quick delivery and easy return) • Accessibility to large number of potential respondents • Use of multiple question formats • Data quality checking • Ease of ensuring confidentiality • Data can be directly captured into database	• Time-consuming development • Potential decrease in return rate due to technological problems • Security issues may threaten validity • *Lack of control over sample* • *Potential for bias in sample*
Email-based (embedded)	• Turnaround time (quick delivery and easy return) • Accessibility to large number of potential respondents	• Possibility of incompatible software • Concern over confidentiality may reduce response rate • Potential for limited access within target population

(Source: Jansen et al, 2007)

3.2 Quantitative Method

3.2.1 Attitude measurement

The concept of attitudes in essential to survey research and although there is presently no consensus on its precise definition, it is commonly agreed that it holds a cognitive component with a Tri-Componential viewpoint. According to the Tri-Componential viewpoint of attitudes, an attitude is a single entity made up of three components commonly referred to as the ABCs of attitude (see Figure 3.1). The cognitive component refers to the ideas and beliefs about an object; the affective component, which is also referred to as the emotional component, encompasses feelings towards an object; and the behavioural component reflects action tendencies towards an object. (Oskamp & Schultz, 2005)

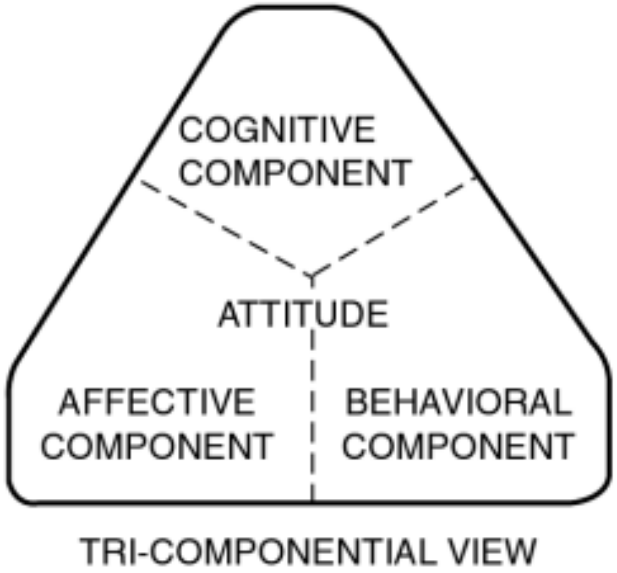

Figure 3.1 Tri-Componential View of Attitudes

In attitude research and consequently in this study, two basic forms of questions are used: open-ended and close-ended questions. Open-ended questions allow the respondent the choice of answering in their own words which has the advantage of avoiding a distortion of the respondent's view and reducing the possibility of excluding a vital viewpoint which the surveyor might have overlooked. However,

a large majority of questionnaires (including the ones used in this study) are majorly made up of closed-ended questions as these are much more easily analysed and are relatively more objective. (Oskamp & Schultz, 2005)

In this study, respondents' agreement with the given statements are measured with the Likert method using clear positive and negative terms with which the respondent indicates their agreement or disagreement.

3.2.2 Questionnaire design

The questionnaires were designed according to questionnaire design guidelines set by Fink (2012) which applies to the construction, layout and content of the questions. However, according to Oskamp (1997), the accuracy of the questionnaires could be compromised by such factors as extremity of responses provided by the respondents and their carelessness. Two questionnaires were administered, one targeting recently graduated CS students and the other any colleagues of such graduates who has supervised the graduate in a professional capacity. The questionnaires were each made up of five sections including an introduction. Tables 3.2 gives an overview of the research objectives and the approaches used to answer the defined research questions (see Table 3.3) while Table 3.4 presents a break-down of the survey questions, explaining their rationale, measurement scales and corresponding research objectives. The actual questionnaires and results can be found in Appendix 1 and 2 respectively.

Table 3.2 Research Objectives and Approaches

Objective	Data Source	Research Questions
1. Investigate existing skill gap in CS graduates	Primary data	- RQ1.1: How relevant are graduate skills to current industry needs? - RQ1.2: How much more training do companies have to provide to new employees?
2. Analyse the difference in expectations between universities, students and the industry.	Primary data	- RQ2.1: An Investigation of the expectation gap: student's abilities and industrial expectations. What are the differences between industry expectations and students' abilities? Recommendations for training computer science graduates to improve sustainability of CS education.

(Source: Author)

Table 3.3 Quantitative Questionnaire Details

Section	No. of Questions	Rationale	Measurement Scale	Objective
Introduction		The introduction briefly presents the research topic and target group of the questionnaire while ensuring strict confidentiality and anonymity. A contact address was also provided for any respondents who would like more information or to follow up on the research. (Fink, 2013)		
Section 1: Background information	5	Gathers background information about the graduate such as how long ago they graduated, their highest qualification and from which country their degree was obtained. Data about the employer (company) is also collected such location and size (number of employees).	Closed Questions with various response alternatives	RO 1
Section 2: Hard Skills – Perception and competencies	3	Gathers data about graduate's competence and respondent's perception of the importance of the listed knowledge areas (hard skills), defined by the IEEE/ACM Computer Science Curricula 2013. And lastly, how much additional training graduates received from their employers in these knowledge areas.	Seven point Likert scale	RO 1 & 2
Section 3: Soft Skills - Perception and competencies	4	Respondents were asked to indicate graduate's competence and how much training graduates had received from their employers on certain soft skills that were selected based on a detailed literature review.	Seven point Likert scale and one open question to suggest any missing skills.	RO 1 & 2
Conclusion	3	Gathers data about respondents' perception of the quality of the graduate's CS education.	Closed Questions with various response alternatives	RO 2

(Source: Author)

3.2.3 Piloting

The quality of data derived from a survey questionnaire relies heavily on respondents' understanding of the questions. Pilot testing is therefore vital to assess respondents' comprehension of the questionnaires and involves presenting survey questionnaires in their final form to respondents who are similar to or in the target population (Bowden et al, 2002). The pilot questionnaire was sent out by email with a request to respondents to assess its ease to understand, flow, time needed to complete the questionnaire, and give recommendations for its improvement (Burns et al, 2008).

Due to time constraints, only four pilot questionnaires were returned with a reported average time of completion of 10 minutes. Apart from one question in section 1 which was not clearly worded and was subsequently rephrased, the questionnaire was very well understood.

3.2.4 Sampling

"A sample is a portion or subset of a larger group called a population"
(Fink, 2003:1).

Collecting data from CS graduates on a global scale was not possible given the time frame of this thesis, therefore a sampling procedure was necessitated. Sampling procedures are generally probability or non-probability. For the purpose of this study, probability sampling was chosen as it gives every person in the population an equal chance to participate in the survey.

3.2.5 Data Collection

The survey was self-administered and was solely distributed online through emails, Twitter and other social media to a random sample. Table 3.3 provides more detail on the data collection process.

Table 3.4 Data Collection Details

	Method
Survey administration	Online (Web/E-mail).
Survey tool	Webropol Surveys (access provided by Lappeenranta University of Technology)
Survey approach	Longitudinal
Sampling method	Probability random sampling
Survey access	Open
Duration of survey	1 April 2015 – 19 May 2015
Responses collected	49
Total view count	156
Response rate	31%

(Source: Author)

3.2.6 Data Analysis Method

The collected quantitative data was analysed following descriptive analysis guidelines detailed by Fink (2012) and Kitchenham et al. (2002). As is often the case with Web-based surveys, the survey was directly connected to a database where the completed survey data was automatically categorized, stored and later analysed using averages, and cross tabulations.

3.3 Summary

This chapter provided a detailed outline of the research and data collection procedure employed in order to obtain reliable and valid results which address the research questions. The chosen statistical approach derived data from self-administered questionnaires which were openly distributed online. Expert standards and guidelines were carefully adhered to in the design, administration and analysis of the questionnaires to ensure the collection of accurate information. The data was coded and analysed using Webropol Surveys and Excel 2013.

4 RESULTS AND DISCUSSION

The results of the quantitative data analysis are presented in this chapter in respect to the RQs. Each research question is presented in an individual sub-chapter. There was a total of 31 respondents to the Graduate survey and 18 respondents to the Graduate's supervisor survey. Figures 4.1 and 4.2 show the country distribution of the Supervisor and Graduate respondents respectively.

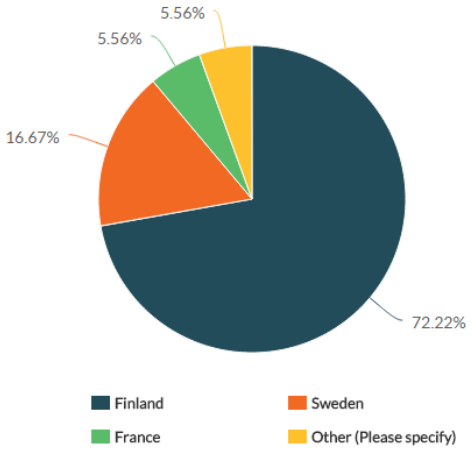

Figure 4.1 Supervisor Respondents' country distribution

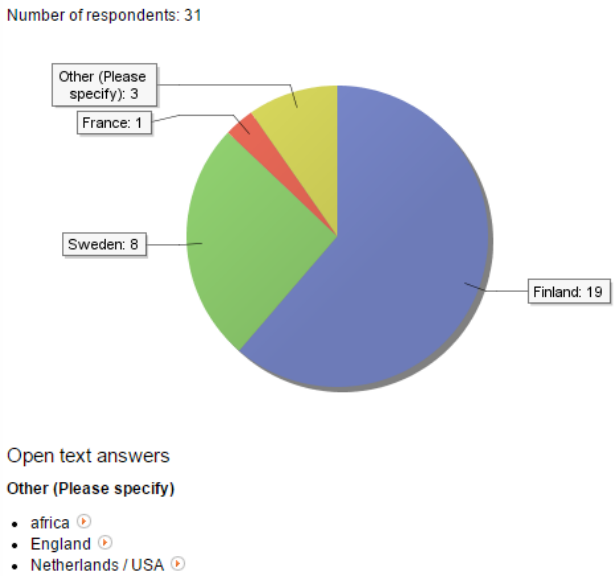

Figure 4.2 Graduate Respondents' country distribution

4.1 Research Objective 1

'Investigate existing skill gap in CS graduates'

To investigate the first objective, two research questions were formulated (RQ1 and RQ2). Respondents of both questionnaires were asked to rate how relevant they considered key computer science knowledge areas, defined in the IEEE/ACM CS Curriculum 2013, to their current job functions.

4.1.1 RQ1.1: How relevant are graduate skills to current industry needs?

Figure 4.3 shows that approximately 85% of the total graduate respondents either agreed or strongly agreed that the defined knowledge areas are useful in their current jobs, with an average of 2.6 (Table 4.1) and Programming Languages and Software Development Fundamentals getting the highest ratings. It can also be observed from figure 4.4 that the highest percentage of graduate supervisor respondents also agree that these KAs are useful to CS graduates in their jobs.

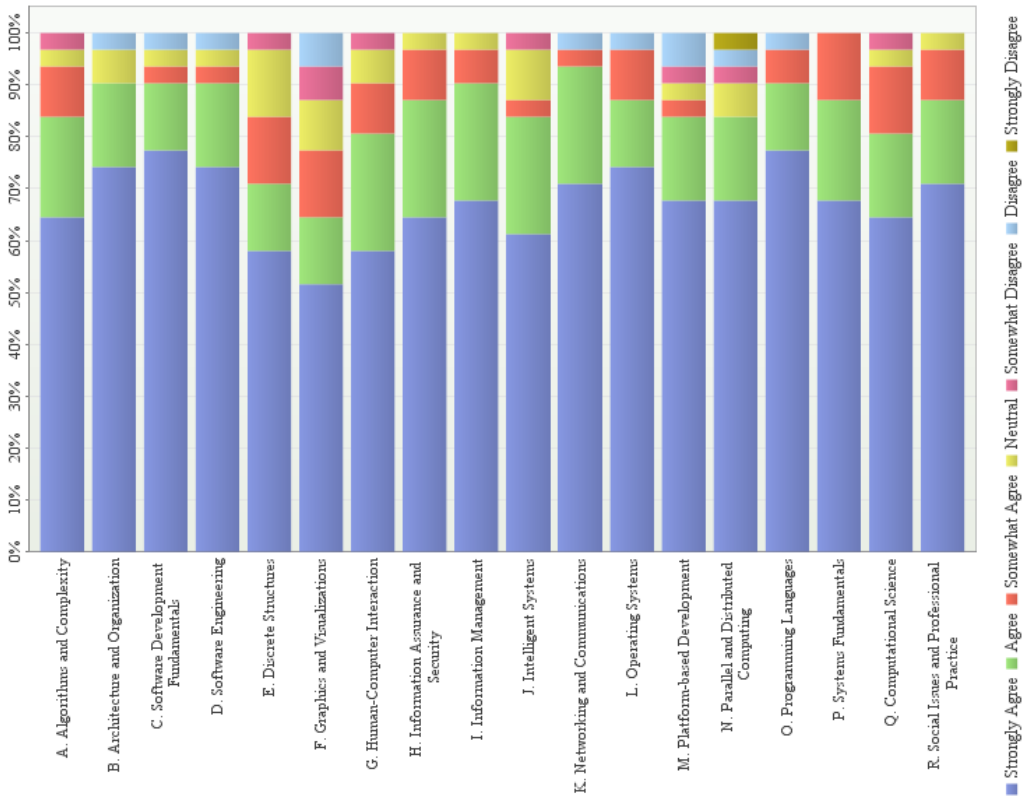

Figure 4.3 Usefulness of CS Knowledge Areas: Graduate Respondents (N=31)

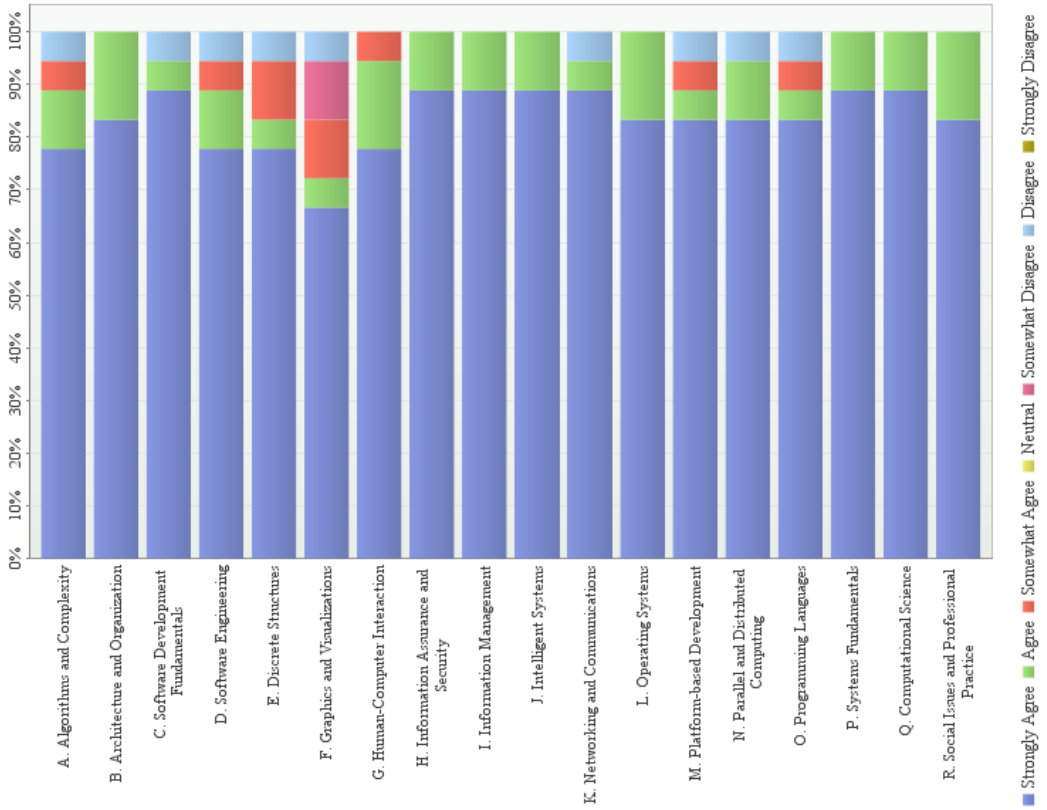

Figure 4.4 Usefulness of CS Knowledge Areas: Supervisor Respondents (N=18)

Table 4.1 Graduate Competence in key Knowledge Areas

Survey Question	Average
How competent are you in terms of understanding concepts from the following knowledge areas?	2.6

On the other hand, in the case of non-technical skills such as critical analysis and teamwork, while majority of both graduate and employer respondents agreed that these skills are essential to the successful performance of their jobs (figures 4.5 & 4.6), less than a quarter of the respondents felt confidence in their competence in these skills.

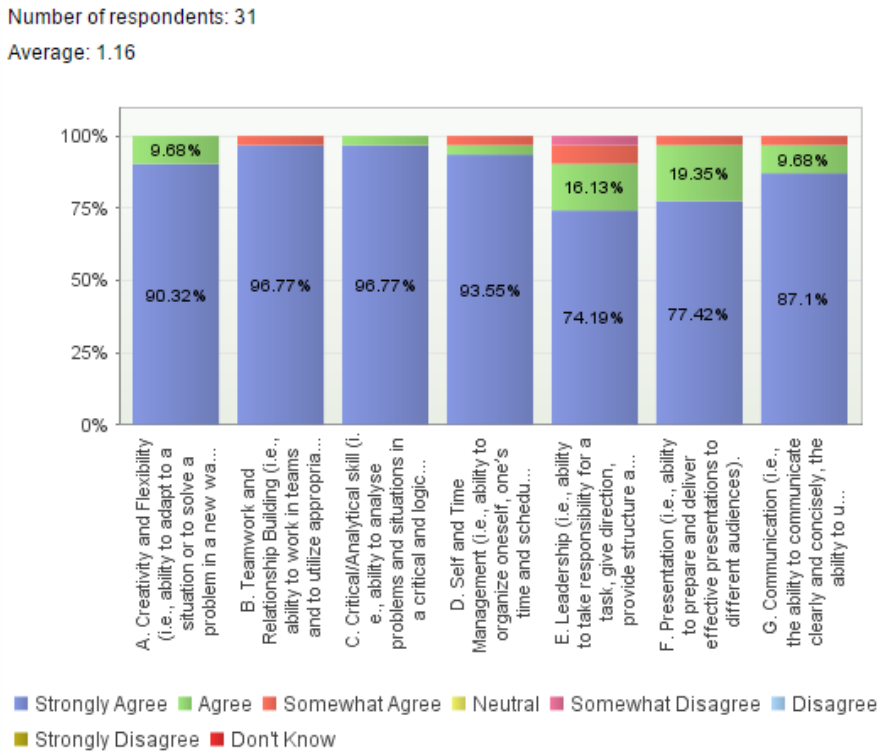

Figure 4.5 Graduates' perception of non-technical competence

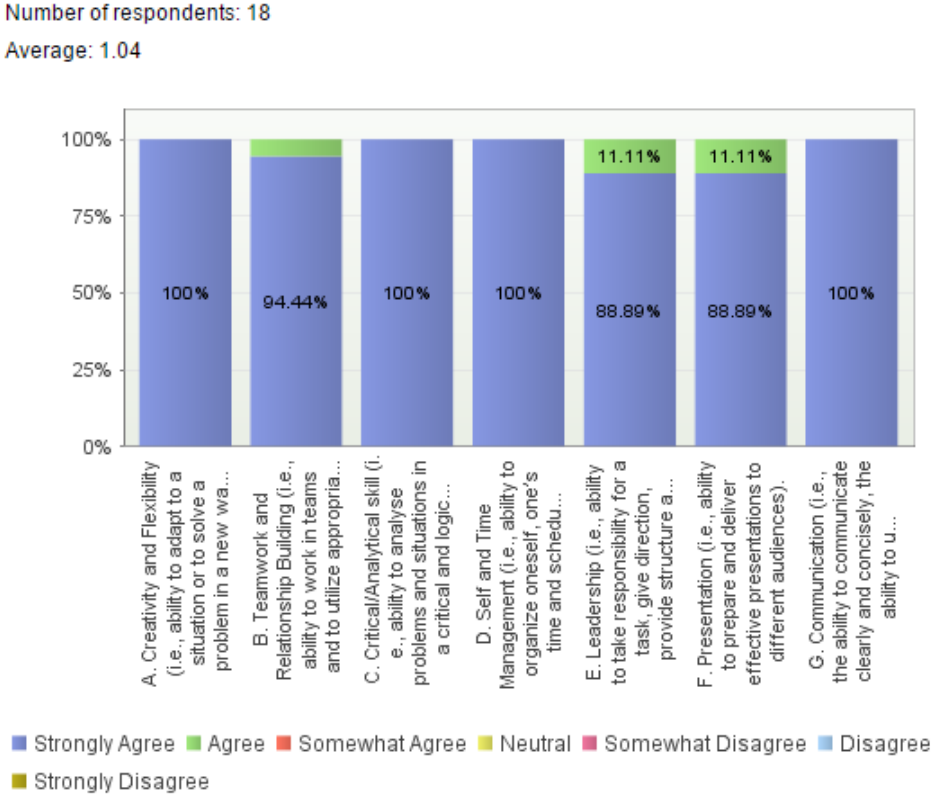

Figure 4.6 Employer perception of graduates' non-technical competence

A high correlation was observed between graduates' competence in non-technical skills and their overall feeling of preparedness for the job market. See Table 4.2. This indicates a strong relationship between both variables leading to the conclusion that graduates who possess a higher level of soft-skill competence generally feel more prepared for the industry.

Table 4.2 Correlation between soft-skill competence and readiness for working life

Variables	Correlation (R)
Graduates' soft-skill competence	0.62
Assessment on readiness for work	

Figures 4.7 and 4.8 show graduate and employer responses to the question of hard skills competence respectively.

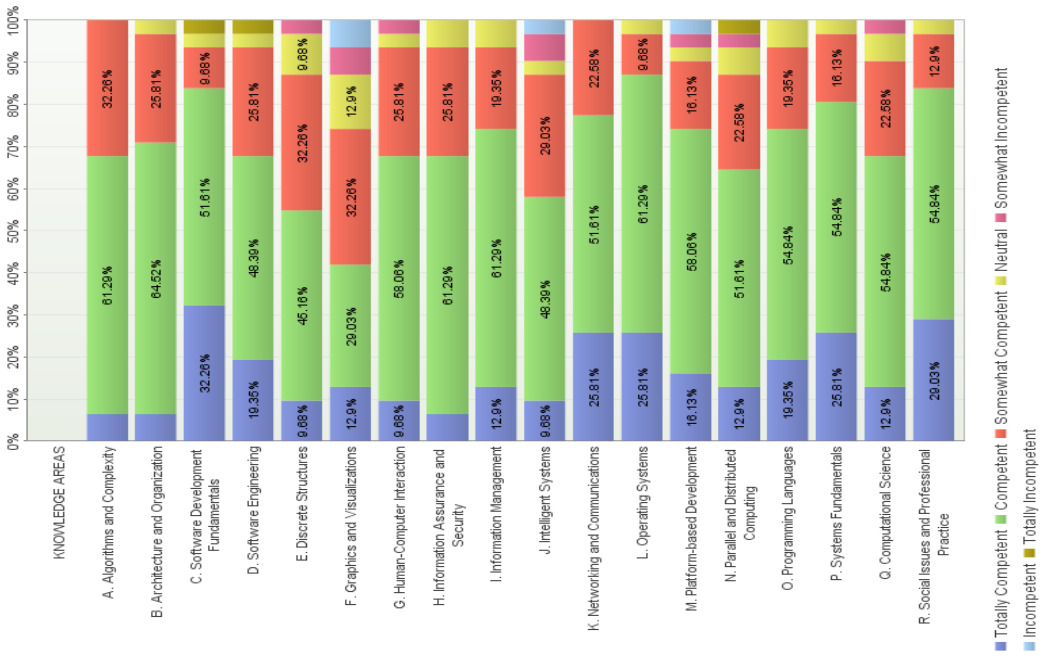

Figure 4.7 Graduate hard-skill competence: Employer perception

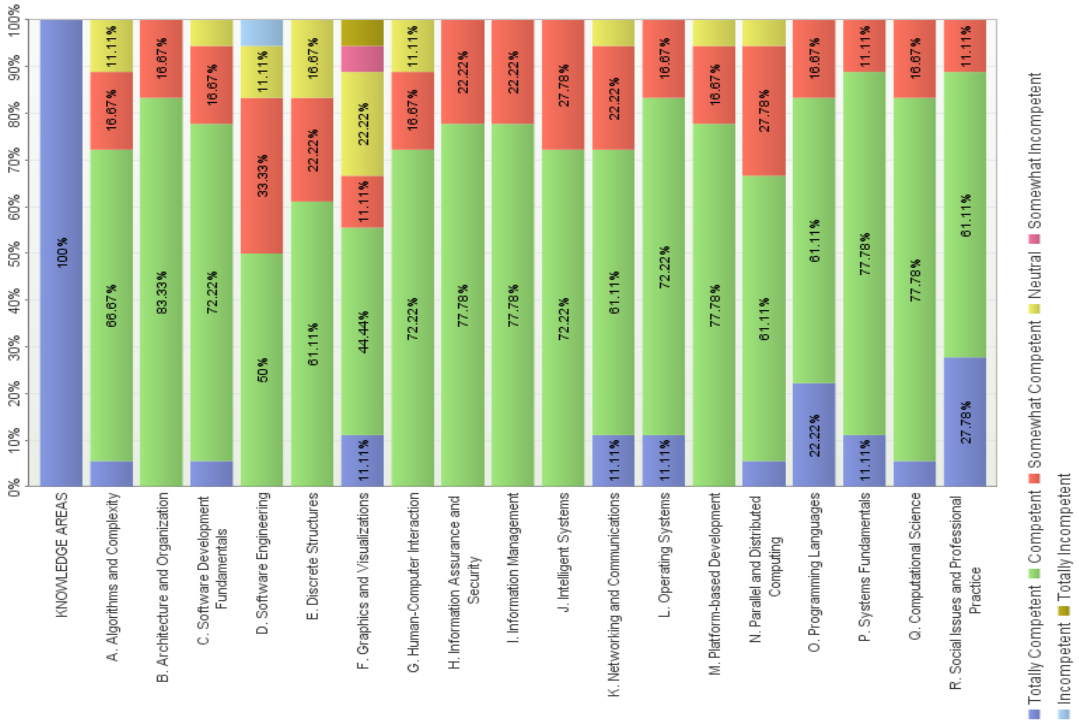

Figure 4.8 Graduate soft-skill competence: Employer perception

4.1.2 RQ1.2: How much more training do companies have to provide to new employees?

According to this study, the skills that seem to be in shortest supply amongst graduates and which companies most often have to provide additional training for are Social Issues and Professional Practice, Information Management, Critical/Analytical thinking, and Relationship building. More than 50% of the 31 graduate respondents had received additional training in these areas. Tables 4.3 and 4.4 show the percentage of graduate surveyors who had received training from their employers.

Table 4.3 Graduates who received additional training (Hard-skills)

Number of respondents: 31

Average: 1.58

	Yes	No	Total
A. Algorithms and Complexity	19.35%	80.65%	31
B. Architecture and Organization	35.48%	64.52%	31
C. Software Development Fundamentals	32.26%	67.74%	31
D. Software Engineering	61.29%	38.71%	31
E. Discrete Structures	19.35%	80.65%	31
F. Graphics and Visualizations	41.94%	58.06%	31
G. Human-Computer Interaction	29.03%	70.97%	31
H. Information Assurance and Security	54.84%	45.16%	31
I. Information Management	61.29%	38.71%	31
J. Intelligent Systems	41.94%	58.06%	31
K. Networking and Communications	64.52%	35.48%	31
L. Operating Systems	45.16%	54.84%	31
M. Platform-based Development	45.16%	54.84%	31
N. Parallel and Distributed Computing	38.71%	61.29%	31
O. Programming Languages	38.71%	61.29%	31
P. Systems Fundamentals	25.81%	74.19%	31
Q. Computational Science	25.81%	74.19%	31
R. Social Issues and Professional Practice	70.97%	29.03%	31
Total	**41.76%**	**58.24%**	**558**

Statistics

Count	Average	Confidence interval	Median	Standard deviation	Skewness	Kurtosis	Entropy
558	1.58	1.54 – 1.62	2	0.49	-0.34	-1.89	0.98

Table 4.4 Graduates who received additional training (Soft-skills)

Number of respondents: 31

Average: 1.53

	Yes	No	Total
A. Creativity and Flexibility (i.e., ability to adapt to a situation or to solve a problem in a new way, openness of mind for new situations, solutions and ideas).	35.48%	64.52%	31
B. Teamwork and Relationship Building (i.e., ability to work in teams and to utilize appropriate interpersonal skills to build relationships with colleagues, team members and external stakeholders).	70.97%	29.03%	31
C. Critical/Analytical skill (i.e., ability to analyse problems and situations in a critical and logical manner),	54.84%	45.16%	31
D. Self and Time Management (i.e., ability to organize oneself, one's time and schedule effectively and reliably).	51.61%	48.39%	31
E. Leadership (i.e., ability to take responsibility for a task, give direction, provide structure and assign responsibility to others).	48.39%	51.61%	31
F. Presentation (i.e., ability to prepare and deliver effective presentations to different audiences).	38.71%	61.29%	31
G. Communication (i.e., the ability to communicate clearly and concisely, the ability to use communication skills to positively influence individual behaviour, using a range of verbal and written methods).	32.26%	67.74%	31
Total	**47.47%**	**52.53%**	**217**

Statistics

Count	Average	Confidence interval	Median	Standard deviation	Skewness	Kurtosis	Entropy
217	1.53	1.46 – 1.59	2	0.5	-0.1	-2.01	1

4.2 Research Objective 2

‘Analyse the difference in expectations between universities, students and the industry’

According to Radermacher et al. (2014), a lack of understanding of job expectations was shown to be one of the foremost problems experienced by recent graduates when working. This raises the question of what the different expectations are between industry, universities and the students.

4.2.1 RQ2.1: What are the differences between industry expectations and students’ abilities?

‘An Investigation of the expectation gap: student’s abilities and industrial expectations. What are the differences between industry expectations and students’ abilities? Recommendations for training computer science graduates to improve sustainability of CS education.’

Universities typically seek to produce CS graduates that are equipped with the right set of skills for employment however the expectation of the desirable competencies of new CS graduates newly entering the workforce may vary depending on the stakeholder’s point of view. (Coll et al., 2006). Coll and Sade (2003) argue that good curriculum design requires a balanced understanding of the views of all education stakeholders.

5 CONCLUSIONS

This thesis examines and discusses the sustainability of Computer Science university curricula by considering the skill gap in the industry. From curricular development practices, that is the approach universities take in deciding what knowledge areas to focus on and how to keep up with the constant evolution in the field of computing, to how much students are being educated on sustainable practices within computer sciences. Overall, it examines how well students transition from academic life to working life and how much additional training they require to perform successfully at their jobs.

According to this study, a skill gap does exist with CS graduates in spite of the fact that graduates seem perfectly competent in the ACM/IEEE defined KAs. The problem seems to lie with the non-technical skills which it seems companies often have to face the challenge of having to provide additional trainings to new hires in this area.

The survey responses show that there is an agreement between CS students and industry on which skills/KAs are considered most important to a successful working life, however CS is a rapidly evolving field and universities are caught in the never-ending struggle of trying to keep up with this evolution.

To ensure the sustainability and adequacy of CS curricula, there needs to be an open channel of communication between the three stakeholders: students, universities and industry. To ensure the sustainability and adequacy of CS curricula, universities must design them in such a way that they are adaptable changes in the field tailored to fit specific classrooms.

5.1 Recommendations for Future Research

This research is merely a first attempt to examine the topic of sustainable computer science curricular development practices, with the quantitative study based majorly in Finland so further research is required to for a more globally rounded view. The results of this study also show an inconsistency in graduates own perception of their competencies and employers perception of graduates' competencies, hence a more detailed study about the perception of competencies and its relation to curricula sustainability would be interesting.

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APPENDICES

Appendix 1. Survey Questionnaires

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Sustainable Computer Science Education - Employer Survey

This survey is part of a Master's thesis research conducted by Lappeenranta University of Technology in collaboration with PERCCOM[1] to assess how well university education prepared Computer Science (CS) graduates for their current jobs and future careers.

The questionnaire is divided into four sections: Background questions, hard skills, soft skills and conclusion. The primary objective is to find out whether recent CS graduates are utilizing and applying the knowledge and skills acquired in their study program, to what degree such knowledge and skills are considered important for their current job and future career development, and how much extra training they required from the company.

All collected data will be handled and stored confidentially, and no data will be released for use of third parties. Survey results will be anonymously analysed and published and it will be impossible to deduct any information on names, associations or answers from these published results.

Please answer questions according to your experiences with one employee who you directly supervise and who has recently completed his or her Computer Science education.

For more information please write to: zainab.matemilola@lut.fi

[1] PERCCOM is an Erasmus Mundus joint European Masters' degree programme in Pervasive Computing & Communications for Sustainable Development. It aims at combining advanced Information and Communication Technologies (ICT) with environmental awareness to enable world-class education and unique competences for ICT professionals who can build cleaner, greener, more resource and energy efficient cyber-physical systems.

I. BACKGROUND QUESTIONS

1. In which country is your organization located? *

- ○ Finland
- ○ Sweden
- ○ France
- ○ Other (Please specify)

2. What is the total number of employees in your organization? *

- ○ < 10
- ○ 10 - 49
- ○ 50 - 99
- ○ 100 - 499
- ○ 500 - 999
- ○ 1000+

3. How long ago did this employee (hereafter referred to as "employee x") graduate from his/her study programme?

- ○ 0 - 5 months
- ○ 6 - 12 months
- ○ More than 12 months

4. From which country did employee X obtain their degree?

- ○ Finland
- ○ France

1/2

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Sustainable Computer Science Education - Employer Survey

II. HARD SKILLS
The following knowledge areas are defined by the IEEE/ACM Computer Science Curricula 2013.

5. Do you agree that the following knowledge areas are *useful* for the performance of employee X's current job functions? (Please check one option per line) *

	Strongly Agree	Agree	Somewhat Agree	Neutral	Somewhat Disagree	Disagree	Strongly Disagree
A. Algorithms and Complexity	○	○	○	○	○	○	○
B. Architecture and Organization	○	○	○	○	○	○	○
C. Software Development Fundamentals	○	○	○	○	○	○	○
D. Software Engineering	○	○	○	○	○	○	○
E. Discrete Structures	○	○	○	○	○	○	○
F. Graphics and Visualizations	○	○	○	○	○	○	○
G. Human-Computer Interaction	○	○	○	○	○	○	○
H. Information Assurance and Security	○	○	○	○	○	○	○
I. Information Management	○	○	○	○	○	○	○
J. Intelligent Systems	○	○	○	○	○	○	○
K. Networking and Communications	○	○	○	○	○	○	○
L. Operating Systems	○	○	○	○	○	○	○
M. Platform-based Development	○	○	○	○	○	○	○
N. Parallel and Distributed Computing	○	○	○	○	○	○	○
O. Programming Languages	○	○	○	○	○	○	○
P. Systems Fundamentals	○	○	○	○	○	○	○
Q. Computational Science	○	○	○	○	○	○	○
R. Social Issues and Professional Practice	○	○	○	○	○	○	○

6. How *competent* is employee X in terms of understanding concepts from the following knowledge areas? (Please check one option per line) *

	Totally Competent	Competent	Somewhat Competent	Neutral	Somewhat Incompetent	Incompetent	Totally Incompetent
KNOWLEDGE AREAS							
A. Algorithms and Complexity	○	○	○	○	○	○	○
B. Architecture and Organization	○	○	○	○	○	○	○
C. Software Development Fundamentals	○	○	○	○	○	○	○
D. Software Engineering	○	○	○	○	○	○	○

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E. Discrete Structures	○	○	○	○	○	○	○
F. Graphics and Visualizations	○	○	○	○	○	○	○
G. Human-Computer Interaction	○	○	○	○	○	○	○
H. Information Assurance and Security	○	○	○	○	○	○	○
I. Information Management	○	○	○	○	○	○	○
J. Intelligent Systems	○	○	○	○	○	○	○
K. Networking and Communications	○	○	○	○	○	○	○
L. Operating Systems	○	○	○	○	○	○	○
M. Platform-based Development	○	○	○	○	○	○	○
N. Parallel and Distributed Computing	○	○	○	○	○	○	○
O. Programming Languages	○	○	○	○	○	○	○
P. Systems Fundamentals	○	○	○	○	○	○	○
Q. Computational Science	○	○	○	○	○	○	○
R. Social Issues and Professional Practice	○	○	○	○	○	○	○

7. *How much additional training,* in each of the following knowledge areas, did your company have to provide to employee X to enable him/her perform his/her job adequately? (Please check one option per line) *

KNOWLEDGE AREAS	Very Much	Much	Somewhat much	Neutral	Somewhat Little	Little	Very Little
A. Algorithms and Complexity	○	○	○	○	○	○	○
B. Architecture and Organization	○	○	○	○	○	○	○
C. Software Development Fundamentals	○	○	○	○	○	○	○
D. Software Engineering	○	○	○	○	○	○	○
E. Discrete Structures	○	○	○	○	○	○	○
F. Graphics and Visualizations	○	○	○	○	○	○	○
G. Human-Computer Interaction	○	○	○	○	○	○	○
H. Information Assurance and Security	○	○	○	○	○	○	○
I. Information Management	○	○	○	○	○	○	○
J. Intelligent Systems	○	○	○	○	○	○	○
K. Networking and Communications	○	○	○	○	○	○	○
L. Operating Systems	○	○	○	○	○	○	○
M. Platform-based Development	○	○	○	○	○	○	○
N. Parallel and Distributed Computing	○	○	○	○	○	○	○
O. Programming Languages	○	○	○	○	○	○	○
P. Systems Fundamentals	○	○	○	○	○	○	○
Q. Computational Science	○	○	○	○	○	○	○
R. Social Issues and Professional Practice	○	○	○	○	○	○	○

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Sustainable Computer Science Education - Employer Survey

III. SOFT SKILLS

8. Do you agree that the following skills are *useful* for employee X's performance of his/her job activities? (Please check one option per line) *

	Strongly Agree	Agree	Somewhat Agree	Neutral	Somewhat Disagree	Disagree	Strongly Disagree
A. Creativity and Flexibility (i.e., ability to adapt to a situation or to solve a problem in a new way, openness of mind for new situations, solutions and ideas).	○	○	○	○	○	○	○
B. Teamwork and Relationship Building (i.e., ability to work in teams and to utilize appropriate interpersonal skills to build relationships with colleagues, team members and external stakeholders).	○	○	○	○	○	○	○
C. Critical/Analytical skill (i.e., ability to analyse problems and situations in a critical and logical manner),	○	○	○	○	○	○	○
D. Self and Time Management (i.e., ability to organize oneself, one's time and schedule effectively and reliably).	○	○	○	○	○	○	○
E. Leadership (i.e., ability to take responsibility for a task, give direction, provide structure and assign responsibility to others).	○	○	○	○	○	○	○
F. Presentation (i.e., ability to prepare and deliver effective presentations to different audiences).	○	○	○	○	○	○	○
G. Communication (i.e., the ability to communicate clearly and concisely, the ability to use communication skills to positively influence individual behaviour, using a range of verbal and written methods).	○	○	○	○	○	○	○

9. How *competent* is employee X in using the following skills at his/her job? (Please check one option per line) *

	Totally Competent	Competent	Somewhat Competent	Neutral	Somewhat Incompetent	Incompetent	Totally Incompetent
A. Creativity and Flexibility (i.e., ability to adapt to a situation or to solve a problem in a new way, openness of mind for new situations, solutions and ideas).	○	○	○	○	○	○	○
B. Teamwork and Relationship Building (i.e., ability to work in teams and to utilize appropriate interpersonal skills to build relationships with colleagues, team members and external stakeholders).	○	○	○	○	○	○	○
C. Critical/Analytical skill (i.e., ability to analyse problems and situations in a critical and logical manner),	○	○	○	○	○	○	○
D. Self and Time Management (i.e., ability to organize oneself, one's time and schedule effectively and reliably).	○	○	○	○	○	○	○
E. Leadership (i.e., ability to take responsibility for a task, give direction, provide structure and assign responsibility	○	○	○	○	○	○	○

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to others).							
F. Presentation (i.e., ability to prepare and deliver effective presentations to different audiences).	○	○	○	○	○	○	○
G. Communication (i.e., the ability to communicate clearly and concisely, the ability to use communication skills to positively influence individual behaviour, using a range of verbal and written methods).	○	○	○	○	○	○	○

10. ***How much additional training,*** in each of the following skills, did your company provide to employee X to enable him/her perform his/her current job adequately? (Please check one option per line) *

	Very Much	Much	Somewhat Much	Neutral	Somewhat Little	Little	Very Little
A. Creativity and Flexibility (i.e., ability to adapt to a situation or to solve a problem in a new way, openness of mind for new situations, solutions and ideas).	○	○	○	○	○	○	○
B. Teamwork and Relationship Building (i.e., ability to work in teams and to utilize appropriate interpersonal skills to build relationships with colleagues, team members and external stakeholders).	○	○	○	○	○	○	○
C. Critical/Analytical skill (i.e., ability to analyse problems and situations in a critical and logical manner),	○	○	○	○	○	○	○
D. Self and Time Management (i.e., ability to organize oneself, one's time and schedule effectively and reliably).	○	○	○	○	○	○	○
E. Leadership (i.e., ability to take responsibility for a task, give direction, provide structure and assign responsibility to others).	○	○	○	○	○	○	○
F. Presentation (i.e., ability to prepare and deliver effective presentations to different audiences).	○	○	○	○	○	○	○
G. Communication (i.e., the ability to communicate clearly and concisely, the ability to use communication skills to positively influence individual behaviour, using a range of verbal and written methods).	○	○	○	○	○	○	○

11. Are there any other skills (in addition to those mentioned in this questionnaire) that you consider also important for the successful performance of employee X's job activities?

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Sustainable Computer Science Education - Employer Survey

III. SOFT SKILLS

8. Do you agree that the following skills are *useful* for employee X's performance of his/her job activities? (Please check one option per line) *

	Strongly Agree	Agree	Somewhat Agree	Neutral	Somewhat Disagree	Disagree	Strongly Disagree
A. Creativity and Flexibility (i.e., ability to adapt to a situation or to solve a problem in a new way, openness of mind for new situations, solutions and ideas).	○	○	○	○	○	○	○
B. Teamwork and Relationship Building (i.e., ability to work in teams and to utilize appropriate interpersonal skills to build relationships with colleagues, team members and external stakeholders).	○	○	○	○	○	○	○
C. Critical/Analytical skill (i.e., ability to analyse problems and situations in a critical and logical manner),	○	○	○	○	○	○	○
D. Self and Time Management (i.e., ability to organize oneself, one's time and schedule effectively and reliably).	○	○	○	○	○	○	○
E. Leadership (i.e., ability to take responsibility for a task, give direction, provide structure and assign responsibility to others).	○	○	○	○	○	○	○
F. Presentation (i.e., ability to prepare and deliver effective presentations to different audiences).	○	○	○	○	○	○	○
G. Communication (i.e., the ability to communicate clearly and concisely, the ability to use communication skills to positively influence individual behaviour, using a range of verbal and written methods).	○	○	○	○	○	○	○

9. How *competent* is employee X in using the following skills at his/her job? (Please check one option per line) *

	Totally Competent	Competent	Somewhat Competent	Neutral	Somewhat Incompetent	Incompetent	Totally Incompetent
A. Creativity and Flexibility (i.e., ability to adapt to a situation or to solve a problem in a new way, openness of mind for new situations, solutions and ideas).	○	○	○	○	○	○	○
B. Teamwork and Relationship Building (i.e., ability to work in teams and to utilize appropriate interpersonal skills to build relationships with colleagues, team members and external stakeholders).	○	○	○	○	○	○	○
C. Critical/Analytical skill (i.e., ability to analyse problems and situations in a critical and logical manner),	○	○	○	○	○	○	○
D. Self and Time Management (i.e., ability to organize oneself, one's time and schedule effectively and reliably).	○	○	○	○	○	○	○
E. Leadership (i.e., ability to take responsibility for a task, give direction, provide structure and assign responsibility	○	○	○	○	○	○	○

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to others).							
F. Presentation (i.e., ability to prepare and deliver effective presentations to different audiences).	○	○	○	○	○	○	○
G. Communication (i.e., the ability to communicate clearly and concisely, the ability to use communication skills to positively influence individual behaviour, using a range of verbal and written methods).	○	○	○	○	○	○	○

10. *How much additional training,* in each of the following skills, did your company provide to employee X to enable him/her perform his/her current job adequately? (Please check one option per line) *

	Very Much	Much	Somewhat Much	Neutral	Somewhat Little	Little	Very Little
A. Creativity and Flexibility (i.e., ability to adapt to a situation or to solve a problem in a new way, openness of mind for new situations, solutions and ideas).	○	○	○	○	○	○	○
B. Teamwork and Relationship Building (i.e., ability to work in teams and to utilize appropriate interpersonal skills to build relationships with colleagues, team members and external stakeholders).	○	○	○	○	○	○	○
C. Critical/Analytical skill (i.e., ability to analyse problems and situations in a critical and logical manner),	○	○	○	○	○	○	○
D. Self and Time Management (i.e., ability to organize oneself, one's time and schedule effectively and reliably).	○	○	○	○	○	○	○
E. Leadership (i.e., ability to take responsibility for a task, give direction, provide structure and assign responsibility to others).	○	○	○	○	○	○	○
F. Presentation (i.e., ability to prepare and deliver effective presentations to different audiences).	○	○	○	○	○	○	○
G. Communication (i.e., the ability to communicate clearly and concisely, the ability to use communication skills to positively influence individual behaviour, using a range of verbal and written methods).	○	○	○	○	○	○	○

11. Are there any other skills (in addition to those mentioned in this questionnaire) that you consider also important for the successful performance of employee X's job activities?

1.

2.

3.

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Sustainable Computer Science Education - Employer Survey

12. Regarding employee X's Computer Science knowledge foundation, how satisfied are you with its overall quality? *

- Very Satisfied
- Satisfied
- Somewhat Satisfied
- Neutral
- Somewhat Dissatisfied
- Dissatisfied
- Very Dissatisfied

13. What is your overall assessment on how well prepared employee X is for succeeding in the job market? *

- Very Well Prepared
- Well Prepared
- Somewhat Prepared
- Neutral
- Somewhat Unprepared
- Unprepared
- Very Unprepared

14. How comfortable would you feel in recommending employee X for other jobs (e.g., in another department within your organization)? Please select one option) *

- Very Comfortable
- Comfortable
- Somewhat Comfortable
- Neutral
- Somewhat Uncomfortable
- Uncomfortable
- Very Uncomfortable

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Sustainable Computer Science Education - Graduate Survey

This survey is part of a Master's thesis research conducted by Lappeenranta University of Technology in collaboration with PERCCOM[1] to assess how well university education prepared Computer Science (CS) graduates for their current jobs and future careers.

The questionnaire is divided into four sections: Background questions, hard skills, soft skills and conclusion. The primary objective is to find out whether recent CS graduates are utilizing and applying the knowledge and skills acquired in their study program, to what degree such knowledge and skills are considered important for their current job and future career development, and how much extra training they required from the company.

All collected data will be handled and stored confidentially, and no data will be released for use of third parties. Survey results will be anonymously analysed and published and it will be impossible to deduct any information on names, associations or answers from these published results.

For more information please write to: zainab.matemilola@lut.fi

[1] PERCCOM is an Erasmus Mundus joint European Masters' degree programme in Pervasive Computing & Communications for Sustainable Development. It aims at combining advanced Information and Communication Technologies (ICT) with environmental awareness to enable world-class education and unique competences for ICT professionals who can build cleaner, greener, more resource and energy efficient cyber-physical systems.

I. BACKGROUND QUESTIONS

1. In which country is your organization located? *

- ○ Finland
- ○ Sweden
- ○ France
- ○ Other (Please specify)

2. What is the total number of employees in your organization? *

- ○ < 10
- ○ 10 - 49
- ○ 50 - 99
- ○ 100 - 499
- ○ 500 - 999
- ○ 1000+

3. What is your highest qualification? *

- ○ Associate Degree
- ○ Bachelor's Degree
- ○ Master's Degree
- ○ PhD
- ○ Other

4. How long ago did you graduate from your study programme? *

- ○ 0 - 5 months
- ○ 6 - 12 months
- ○ More than 12 months

5. From which country did you obtain your degree?

- ○ Finland
- ○ France
- ○ Sweden
- ○ Other (Please specify)

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Sustainable Computer Science Education - Graduate Survey

II. HARD SKILLS
The following knowledge areas are defined by the IEEE/ACM Computer Science Curricula 2013.

6. Do you agree that the following knowledge areas are *useful* for the performance of your current job functions? (Please check one option per line) *

	Strongly Agree	Agree	Somewhat Agree	Neutral	Somewhat Disagree	Disagree	Strongly Disagree
A. Algorithms and Complexity	○	○	○	○	○	○	○
B. Architecture and Organization	○	○	○	○	○	○	○
C. Software Development Fundamentals	○	○	○	○	○	○	○
D. Software Engineering	○	○	○	○	○	○	○
E. Discrete Structures	○	○	○	○	○	○	○
F. Graphics and Visualizations	○	○	○	○	○	○	○
G. Human-Computer Interaction	○	○	○	○	○	○	○
H. Information Assurance and Security	○	○	○	○	○	○	○
I. Information Management	○	○	○	○	○	○	○
J. Intelligent Systems	○	○	○	○	○	○	○
K. Networking and Communications	○	○	○	○	○	○	○
L. Operating Systems	○	○	○	○	○	○	○
M. Platform-based Development	○	○	○	○	○	○	○
N. Parallel and Distributed Computing	○	○	○	○	○	○	○
O. Programming Languages	○	○	○	○	○	○	○
P. Systems Fundamentals	○	○	○	○	○	○	○
Q. Computational Science	○	○	○	○	○	○	○
R. Social Issues and Professional Practice	○	○	○	○	○	○	○

7. How *competent* are you in terms of understanding concepts from the following knowledge areas? (Please check one option per line) *

	Totally Competent	Competent	Somewhat Competent	Neutral	Somewhat Incompetent	Incompetent	Totally Incompetent
KNOWLEDGE AREAS							
A. Algorithms and Complexity	○	○	○	○	○	○	○
B. Architecture and Organization	○	○	○	○	○	○	○
C. Software Development Fundamentals	○	○	○	○	○	○	○

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Sustainable Computer Science Education - Graduate Survey

III. SOFT SKILLS

9. Do you agree that the following skills are *useful* for the performance of your current job activities? (Please check one option per line) *

	Strongly Agree	Agree	Somewhat Agree	Neutral	Somewhat Disagree	Disagree	Strongly Disagree	Don't Know
A. Creativity and Flexibility (i.e., ability to adapt to a situation or to solve a problem in a new way, openness of mind for new situations, solutions and ideas).	○	○	○	○	○	○	○	○
B. Teamwork and Relationship Building (i.e., ability to work in teams and to utilize appropriate interpersonal skills to build relationships with colleagues, team members and external stakeholders).	○	○	○	○	○	○	○	○
C. Critical/Analytical skill (i.e., ability to analyse problems and situations in a critical and logical manner),	○	○	○	○	○	○	○	○
D. Self and Time Management (i.e., ability to organize oneself, one's time and schedule effectively and reliably).	○	○	○	○	○	○	○	○
E. Leadership (i.e., ability to take responsibility for a task, give direction, provide structure and assign responsibility to others).	○	○	○	○	○	○	○	○
F. Presentation (i.e., ability to prepare and deliver effective presentations to different audiences).	○	○	○	○	○	○	○	○
G. Communication (i.e., the ability to communicate clearly and concisely, the ability to use communication skills to positively influence individual behaviour, using a range of verbal and written methods).	○	○	○	○	○	○	○	○

10. How *competent* are you in using the following skills at your job? (Please check one option per line) *

	Totally Competent	Competent	Somewhat Competent	Neutral	Somewhat Incompetent	Incompetent	Totally Incompetent
A. Creativity and Flexibility (i.e., ability to adapt to a situation or to solve a problem in a new way, openness of mind for new situations, solutions and ideas).	○	○	○	○	○	○	○
B. Teamwork and Relationship Building (i.e., ability to work in teams and to utilize appropriate interpersonal skills to build relationships with colleagues, team members and external stakeholders).	○	○	○	○	○	○	○

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(Appendix 1 continued)

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Sustainable Computer Science Education - Graduate Survey

13. Regarding your Computer Science knowledge foundation, how satisfied are you with its overall quality? *

- ○ Very Satisfied
- ○ Satisfied
- ○ Somewhat Satisfied
- ○ Neutral
- ○ Somewhat Dissatisfied
- ○ Dissatisfied
- ○ Very Dissatisfied

14. What is your overall assessment on how well prepared you are for succeeding in the job market? *

- ○ Very Well Prepared
- ○ Well Prepared
- ○ Somewhat Prepared
- ○ Neutral
- ○ Somewhat Unprepared
- ○ Unprepared
- ○ Very Unprepared

15. How satisfied are you with your job performance in general? *

- ○ Very Satisfied
- ○ Satisfied
- ○ Somewhat Satisfied
- ○ Neutral
- ○ Somewhat Dissatisfied
- ○ Dissatisfied
- ○ Very Dissatisfied

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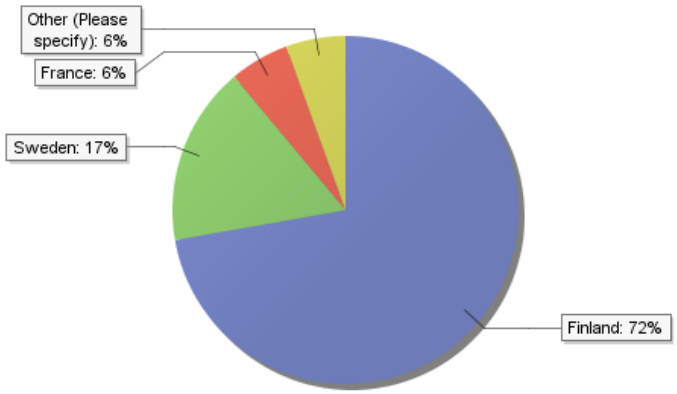
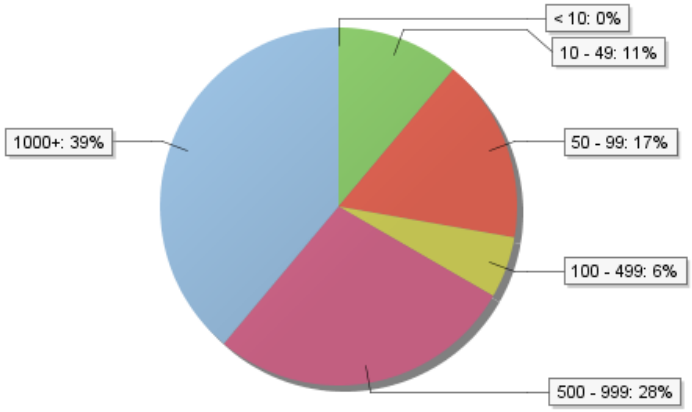
Appendix 2. Survey Results

Employer Survey Results

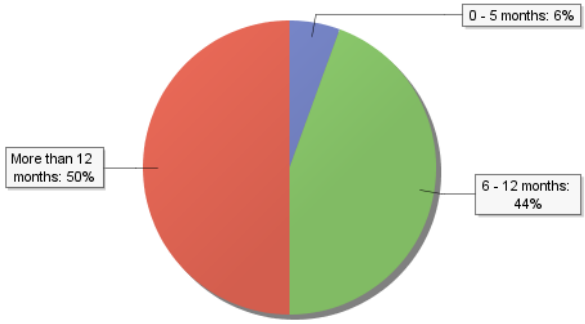
1. In which country is your organization located?
Number of respondents: 18
Average: 1.44



2. What is the total number of employees in your organization?
Number of respondents: 18
Average: 4.67



3. How long ago did this employee (hereafter referred to as "employee x") graduate from his/her study programme?
Number of respondents: 18



Average: 2.44

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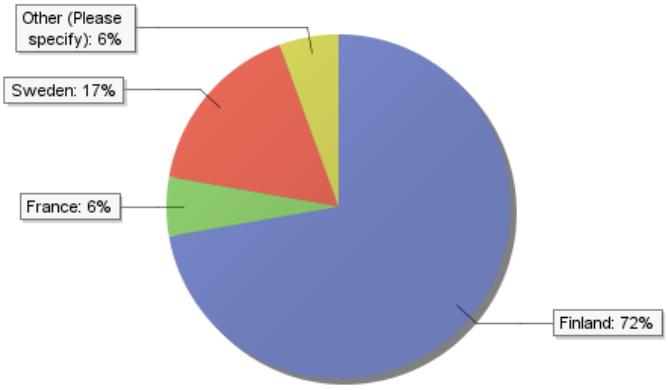
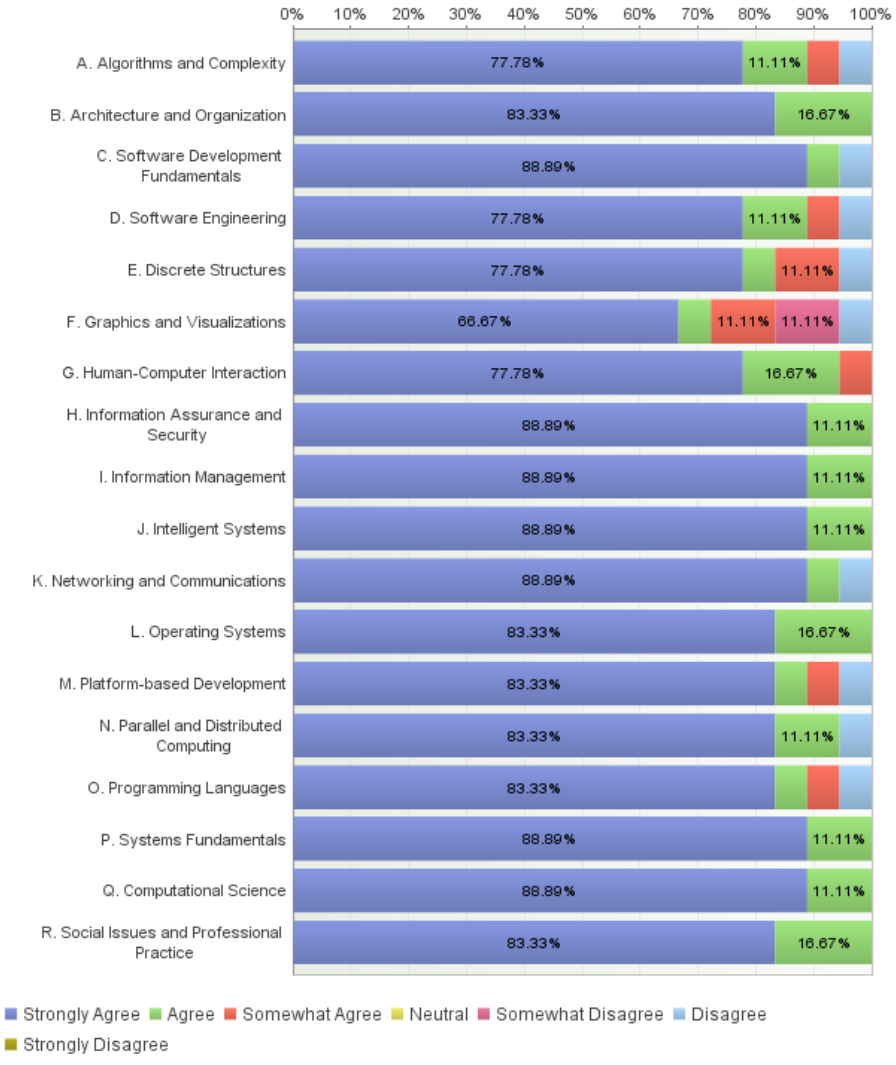
(Appendix 2 continued)

4. From which country did employee X obtain their degree?
Number of respondents: 18
Average: 1.56



5. Do you agree that the following knowledge areas are useful for the performance of employee X's current job functions? (Please check one option per line)
Number of respondents: 18
Average: 1.32



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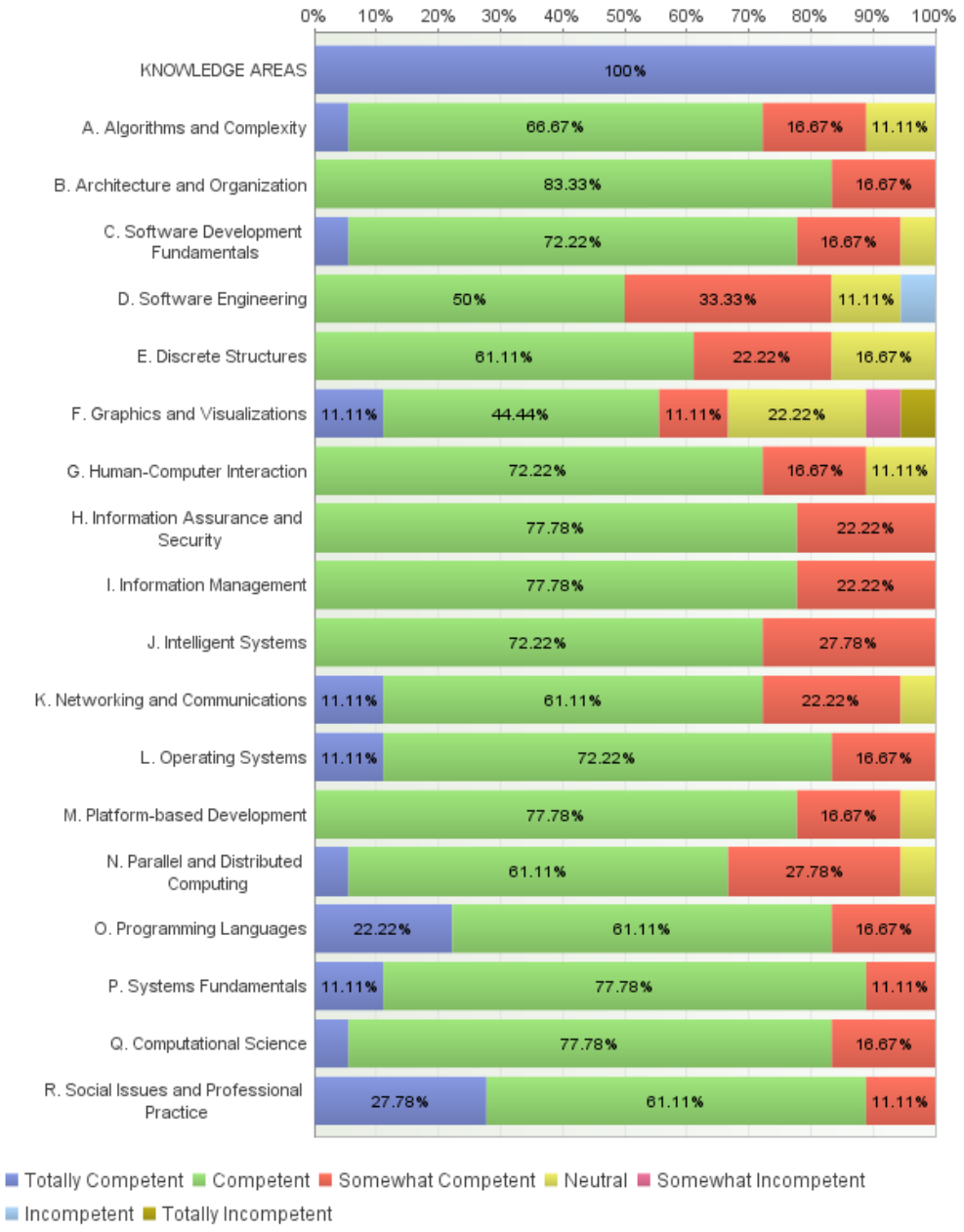
(Appendix 2 continued)

6. How competent is employee X in terms of understanding concepts from the following knowledge areas? (Please check one option per line)
Number of respondents: 18
Average: 2.26



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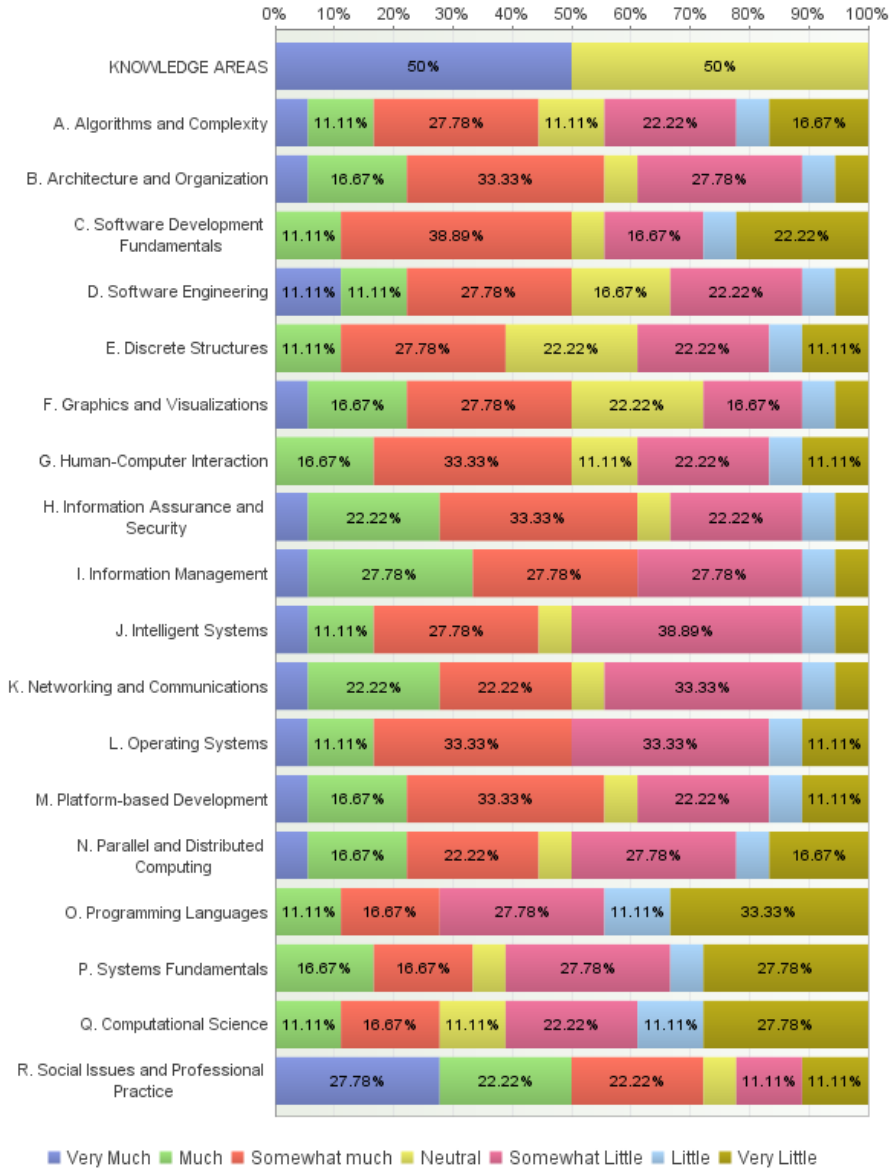
(Appendix 2 continued)

7. How much additional training, in each of the following knowledge areas, did your company have to provide to employee X to enable him/her perform his/her job adequately? (Please check one option per line)

Number of respondents: 18

Average: 4.01



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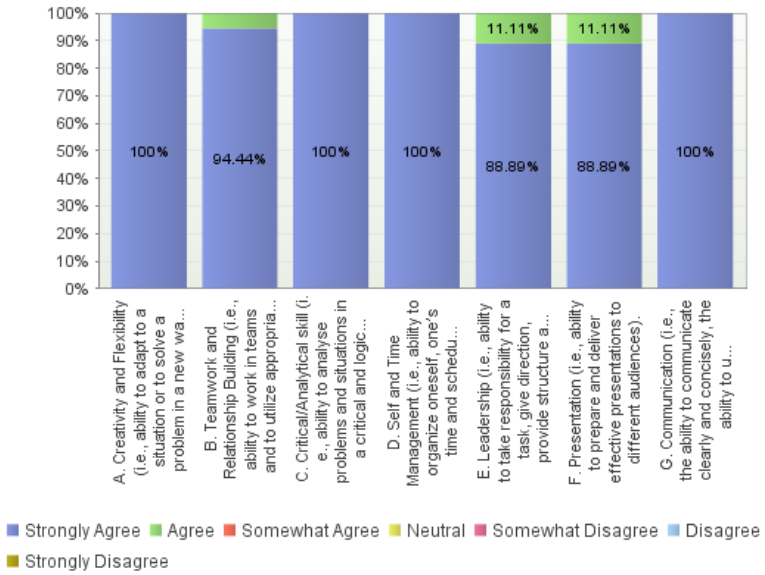
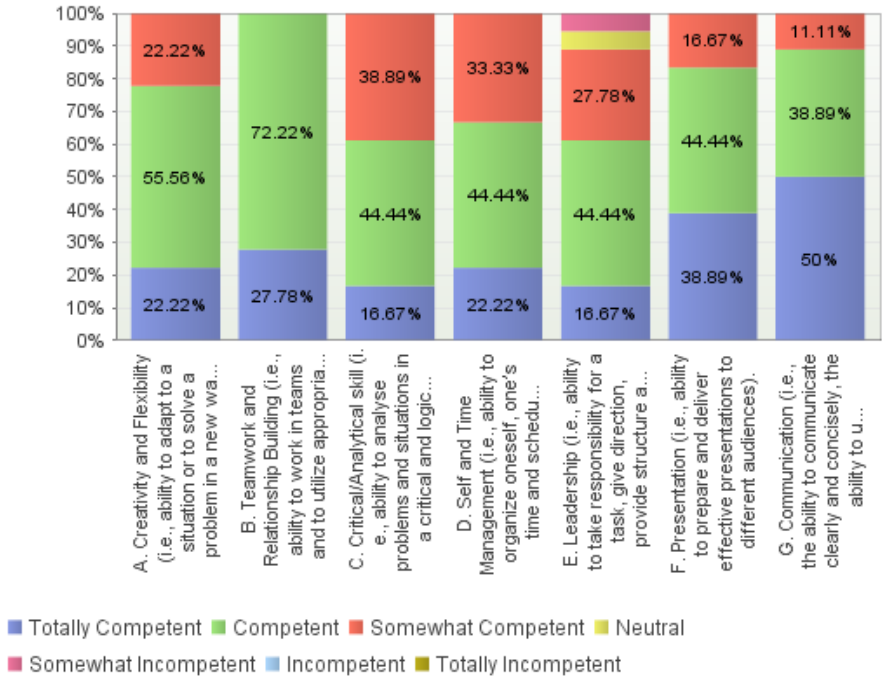
(Appendix 2 continued)

8. Do you agree that the following skills are useful for employee X's performance of his/her job activities? (Please check one option per line)
Number of respondents: 18
Average: 1.04



9. How competent is employee X in using the following skills at his/her job? (Please check one option per line)
Number of respondents: 18
Average: 1.98



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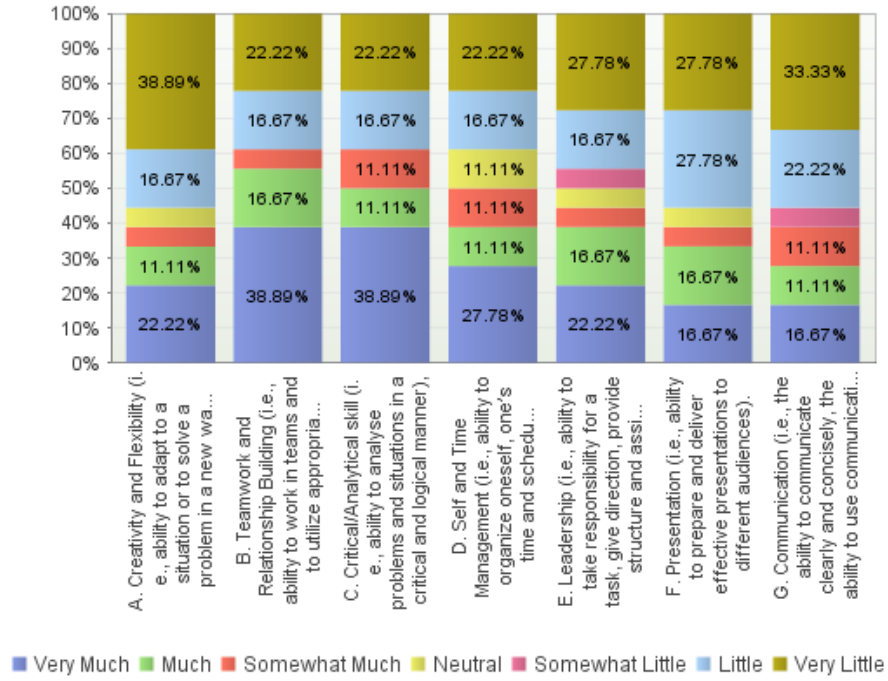
(Appendix 2 continued)

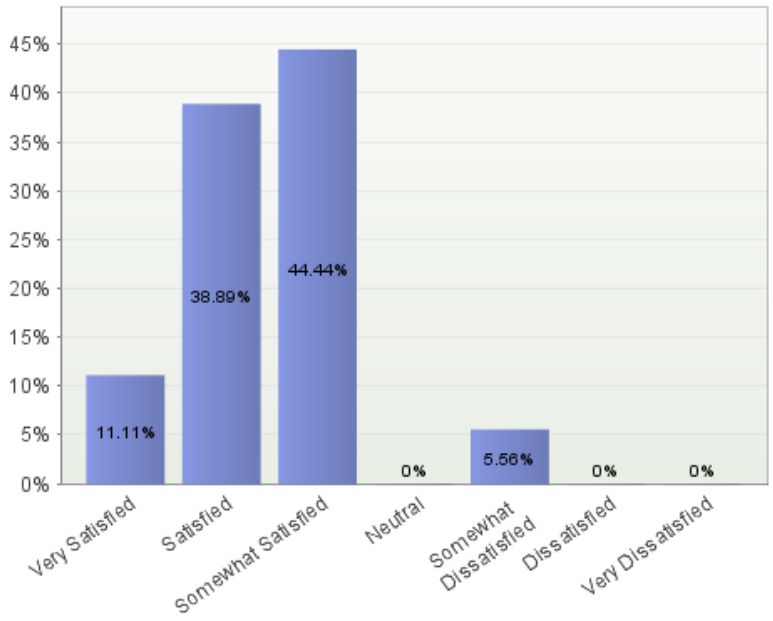
10. How much additional training, in each of the following skills, did your company provide to employee X to enable him/her perform his/her current job adequately? (Please check one option per line)

Number of respondents: 18
Average: 4.1



11. Regarding employee X's Computer Science knowledge foundation, how satisfied are you with its overall quality?

Number of respondents: 18
Average: 2.5



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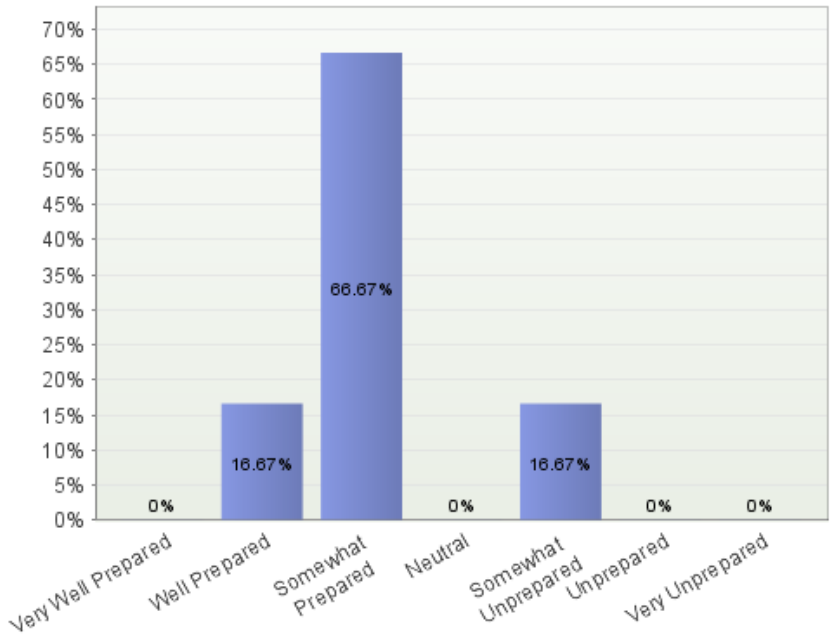
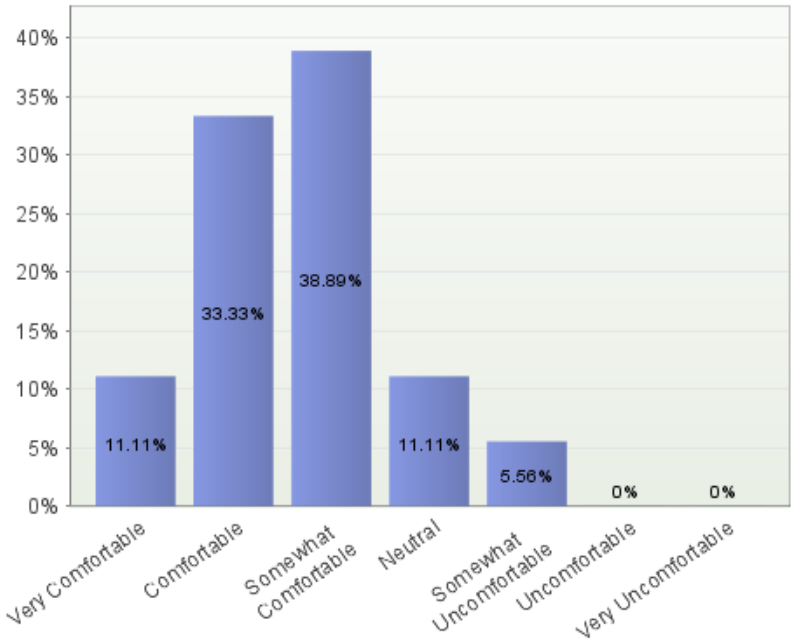
(Appendix 2 continued)

12. What is your overall assessment on how well prepared employee X is for succeeding in the job market?
Number of respondents: 18
Average: 3.17



13. How comfortable would you feel in recommending employee X for other jobs (e.g., in another department within your organization)? Please select one option)
Number of respondents: 18
Average: 2.67



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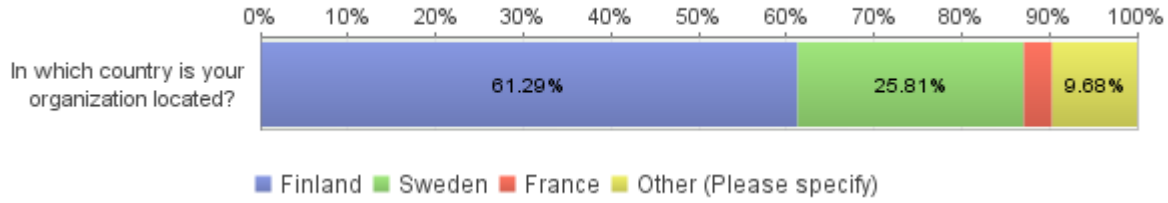
(Appendix 2 continued)

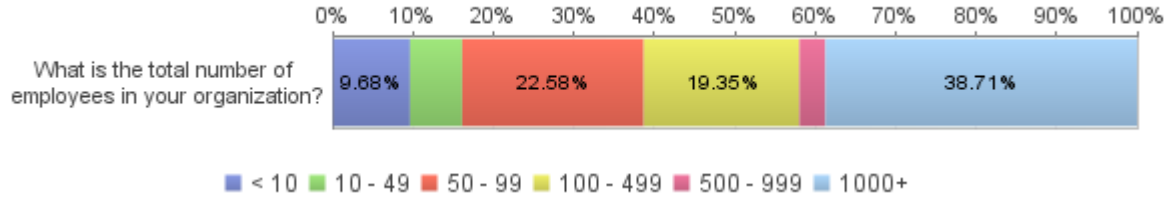
Graduate Survey Results

1. In which country is your organization located?
Number of respondents: 31
Average: 1.61

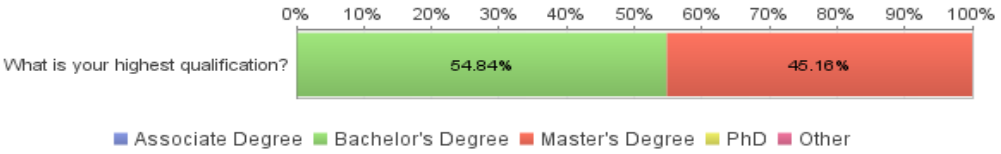


Open text answers: Other (Please specify)
- Africa
- England
- Netherlands / USA

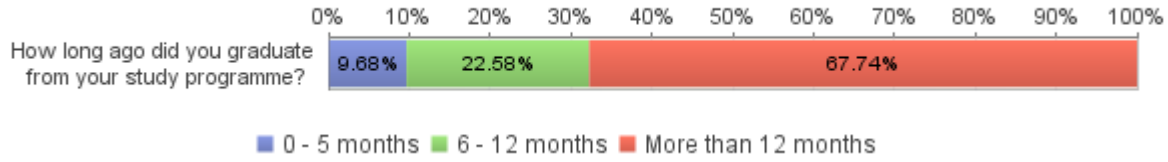
2. What is the total number of employees in your organization?
Number of respondents: 31
Average: 4.16



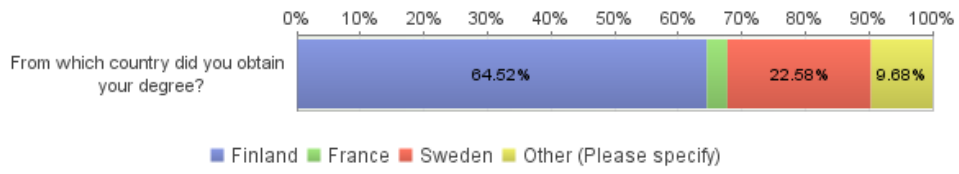
3. What is your highest qualification?
Number of respondents: 31
Average: 2.45



4. How long ago did you graduate from your study programme?
Number of respondents: 31
Average: 2.58



5. From which country did you obtain your degree?
Number of respondents: 31
Average: 1.77



Other (Please specify): England/UK

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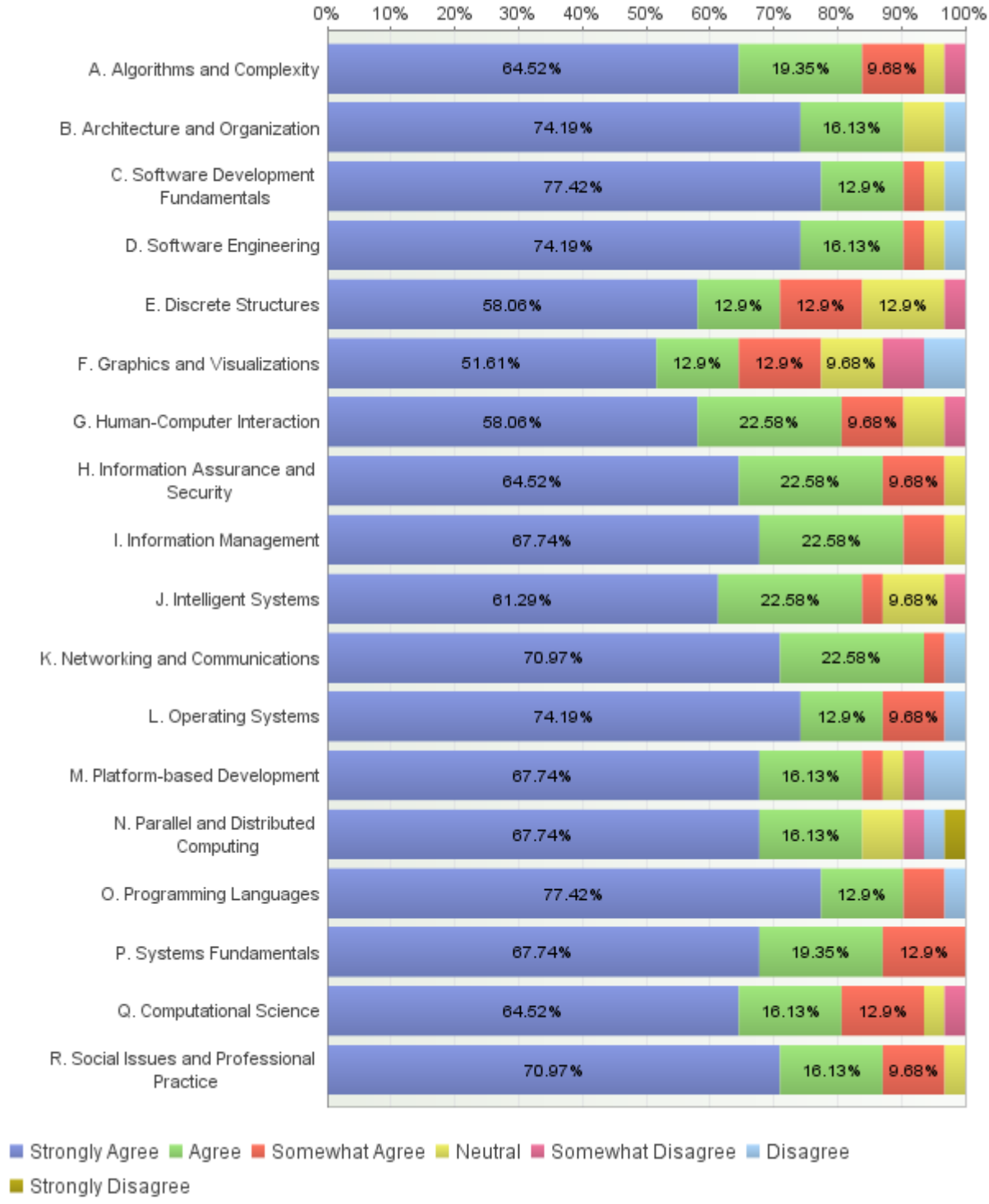
(Appendix 2 continued)

6. Do you agree that the following knowledge areas are useful for the performance of your current job functions? (Please check one option per line)
Number of respondents: 31
Average: 1.62



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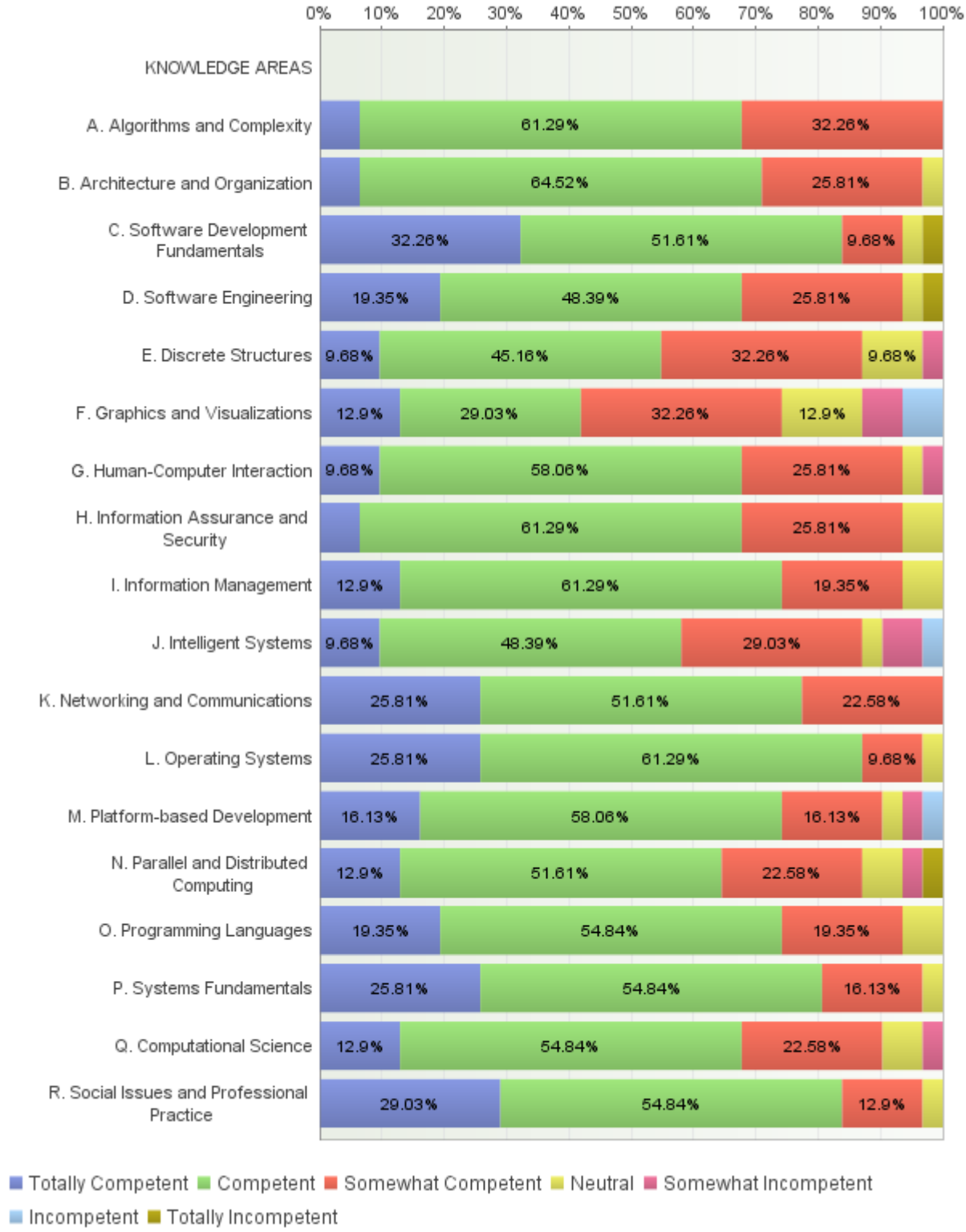
(Appendix 2 continued)

7. How competent are you in terms of understanding concepts from the following knowledge areas? (Please check one option per line)
Number of respondents: 31
Average: 2.26



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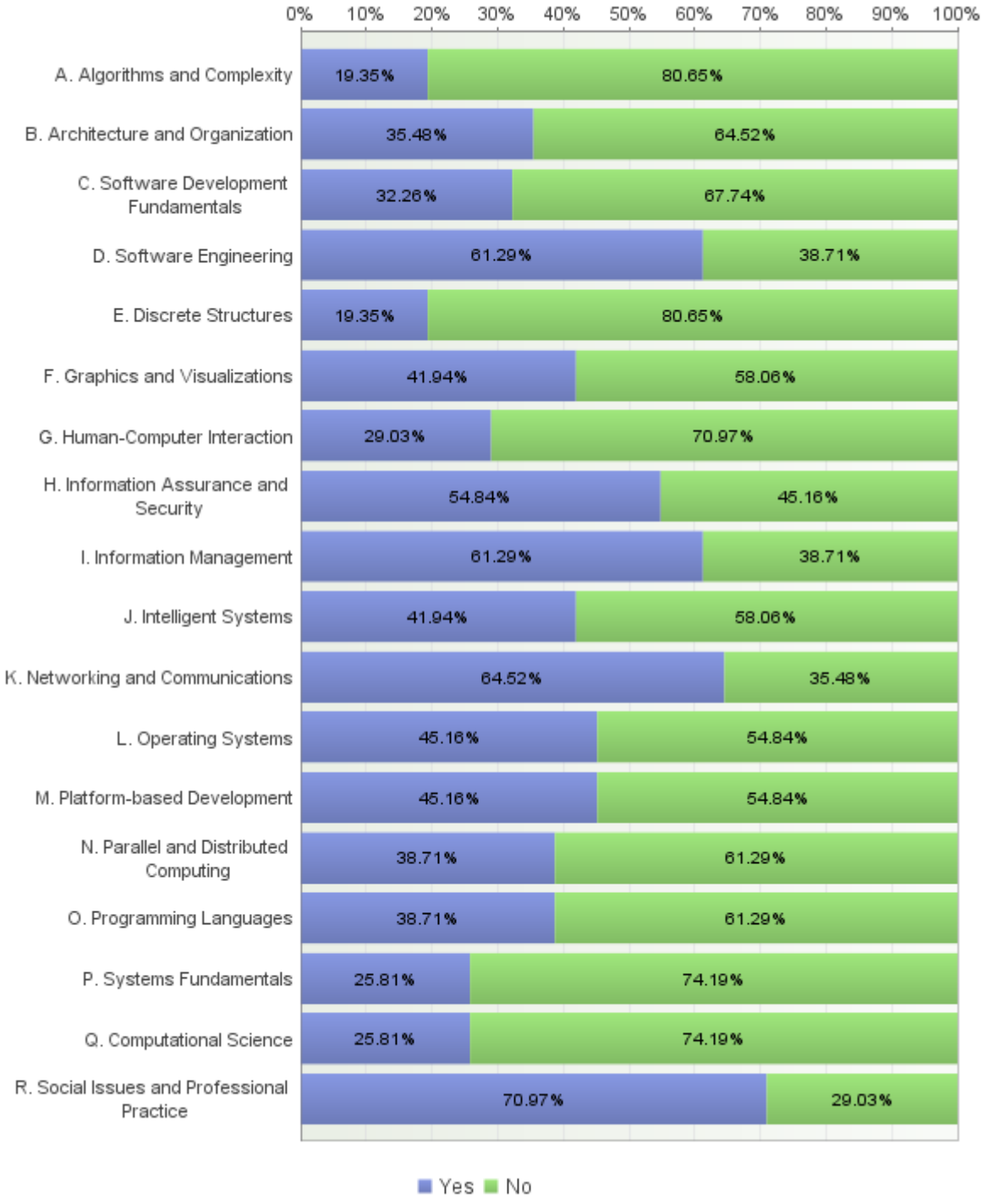
(Appendix 2 continued)

8. Have you received additional training from your company in any of the following knowledge areas? (Please check one option per line)
Number of respondents: 31
Average: 1.58



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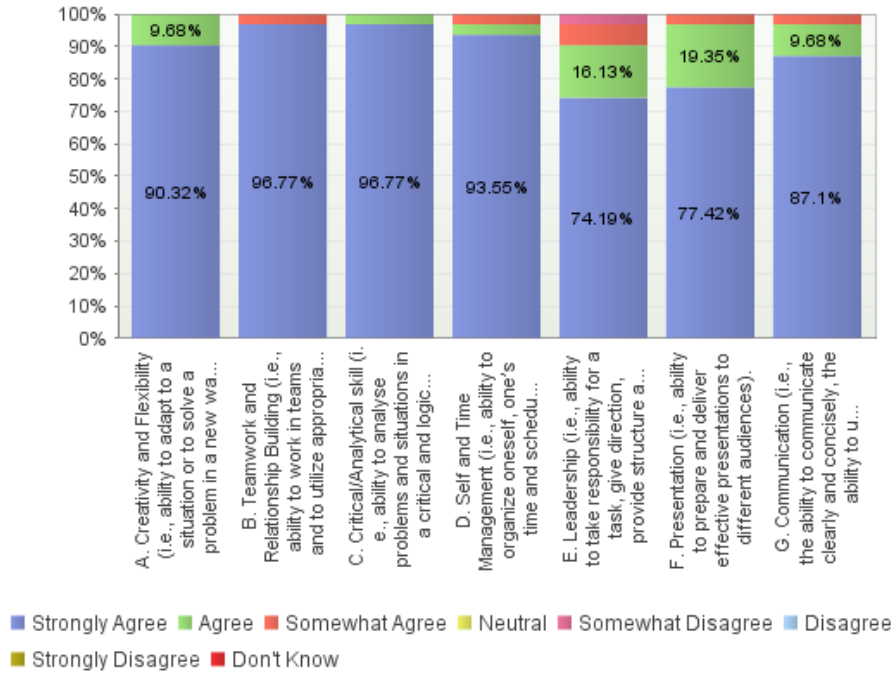
(Appendix 2 continued)

9. Do you agree that the following skills are useful for the performance of your current job activities? (Please check one option per line)
Number of respondents: 31
Average: 1.16



10. How competent are you in using the following skills at your job? (Please check one option per line)
Number of respondents: 31
Average: 2.36

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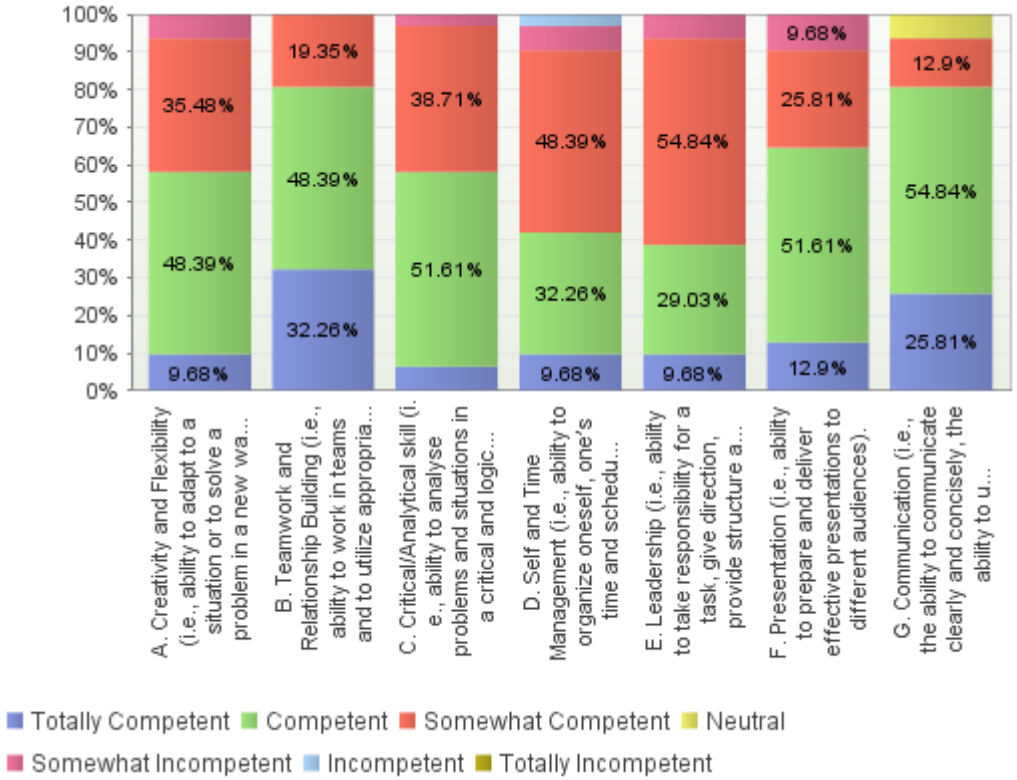
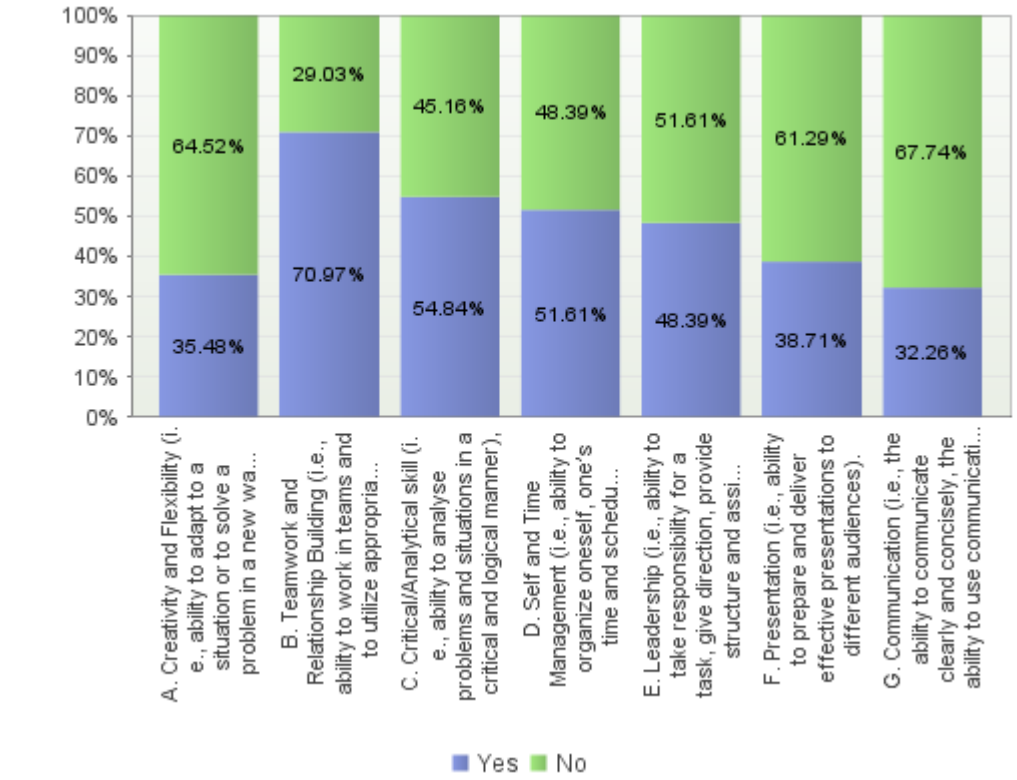


11. Have you received any additional training from your company in any of the following areas? (Please check one option per line)
Number of respondents: 31
Average: 1.53



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(Appendix 2 continued)

12. Are there any other skills (in addition to those mentioned in this questionnaire) that you consider also important for the successful performance of your current job responsibilities?

Number of respondents: 1

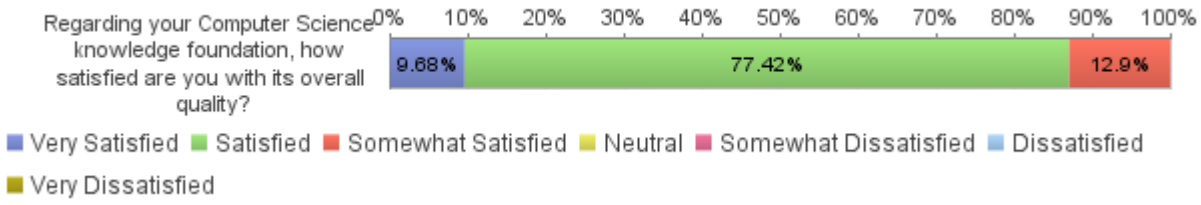
1.
- Customer service skills (internal & external)

2.
- Internet marketing

3.
- Mobile development

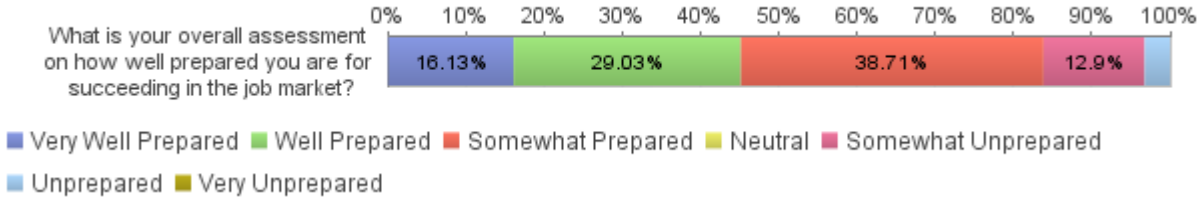
13. Regarding your Computer Science knowledge foundation, how satisfied are you with its overall quality?

Number of respondents: 31
Average: 2.03



14. What is your overall assessment on how well prepared you are for succeeding in the job market?

Number of respondents: 31
Average: 2.74



15. How satisfied are you with your job performance in general?

Number of respondents: 31
Average: 2.19