

# Education and skills for the successful development of information technology projects in South Africa

*Washington Mtembo  
University of South Africa  
South Africa*

*Sheryl Buckley  
University of South Africa  
South Africa*

## **Abstract**

Nowadays software is pervasive – not just in processing your bank account details and booking a holiday, but also in automotive systems (cruise control, braking systems), medical devices (pacemakers and insulin pumps), and even everyday appliances such as washing machines, burglar alarms, televisions and clocks. While there is an increasing amount of information technology (IT) development, the Standish Group (*Chaos report 2014*) shows that a small number (16.2%) of IT projects worldwide are successful, with 31.1% being challenged prior to completion and 52.7% costing as much as twice their original estimate. The Gartner survey (Mieritz 2012) on why projects fail, suggests that a major cause is the challenge of identifying, building and developing the skills and allocating the staff required for highly effective project and programme leadership. The current paper explores the enterprise system skills needed for the IT industry and education within the South African context. The paper assesses the awareness of software engineering students and lecturers at South African universities, with respect to those enterprise system skills which are most in demand. The paper assesses the weakness of the newly hired software engineering graduate, based on the opinions of IT industry practitioners, and determines what skills IT industries will expect from graduates in the near future. To build a more detailed understanding, a quantitative method was used. This was supported by surveys conducted via an online questionnaire sent to respondents across South Africa: from academics to IT industry practitioners. The data collected were analysed statistically. The study seeks to provide a future perspective of software engineering education that addresses the success rate of IT projects in South Africa. Educational institutes can benefit by using this perspective as a basic for their training programmes.

## **Keywords**

Enterprise system skills, education, Information Technology projects, developing countries

# 1. Introduction

## 1.1 Background

Nowadays software is pervasive – not just in processing bank account details and booking holidays, but also in automotive systems (cruise control, braking systems), medical devices (pacemakers and insulin pumps), and even everyday appliances such as washing machines, burglar alarms, televisions and clocks. South African industries are rapidly growing thanks to advances in science and technology and project funding is increasingly spent within this context, whether through the development of new technologies or systems, the upgrading of existing systems, or the maintenance and outsourcing of current technologies and systems (Bartels 2007). According to the Standish Group (*Chaos report* 2014), a small number (16.2%) of IT projects worldwide are successful. The Standish Group considers a project to be successful if it meets three requirements: completed on time, within the allotted budget and with the required functionality. Statistics show that 31.1% of such projects are challenged prior to completion, while 52.7% cost twice their original estimates (Clancy 2014).

Successful IT projects require a staff of IT professionals who are innovative, hardworking, forward-thinking and globally sensitive. The Gartner survey (Mieritz 2012) on why projects fail suggests that some of the major causes lie in the challenge of identifying, building and developing the skills and staff required for highly effective project and programme leadership. Various frameworks and methodologies are currently available to assist in striking a balance between the education and skills needed for the successful development of IT projects. However, most of these frameworks and methodologies originate in Western/European countries, and are designed to address education and enterprise system skills within their respective environments. Consequently, these frameworks might not be suitable for South Africa to adopt. There is thus a need to investigate the applicability and effectiveness of education and enterprise system skills for the successful development of IT projects in a local context.

Software engineering is the study and application of engineering to the design, development and maintenance of software with a limited budget and a given deadline. Software engineering education in South Africa currently faces a major problem. The Department of Labour's *Annual Report* (2014) shows that current software engineering graduates lack the necessary enterprise system skills and experience to join industry, because they were subjected to poor preparation during their university studies.

## 1.2 Objectives of the paper

The study seeks to identify the future software engineering education and enterprise system skills needed to address the success rate of IT projects in South Africa. The objectives of the paper are:

- To explore enterprise systems skills for the IT industry within the South African context;
- To assess the awareness of software engineering students and lecturers at South African universities as regards the most in-demand enterprise system skills;
- To assess the weakness of the newly hired software engineering graduate, based on the opinions of IT industry stakeholders;

- To determine what skills IT industries expect to require in the near future.

## 2 Literature review

The enterprise system skills that software engineering students have acquired by the time they graduate, play an important role in their employability and ultimately the success of IT projects. Several discussions in recent years have focused on an apparent disparity between the skills in demand in the industry, and those generated by education (Institute of Mechanical Engineers 2013). Ayofe (2009), who examined the skills gap between the industrial application of IT and Nigerian universities' computer science programmes, suggests that the solution lies in blending academic rigidity with industry relevance. Koong (2002) analysed the listings in two job databases and found that over half of all job opportunities were in the area of programming languages and Web development. Koong (2002) also found that a great majority of the jobs required the ideal candidate to have multiple classes or categories of skills. Lethbridge (2000) questioned 186 interviewees from different educational backgrounds about 75 educational topics, while Kitchenham (2005) adapted a survey instrument developed by Lethbridge to assess the extent to which the education delivered by four universities in the United Kingdom corresponds to the requirements of the software industry. Amiri (2011) recommended that software engineering curricula be revised by managers within the software industry. In his research, software engineering curricula in Iran were presented to software managers, who were asked to identify a curriculum as either an essential or as an elective course, while a third option was to remove it from the curriculum.

## 3 Research design

To realise the identified objectives, the quantitative method was used, supported by surveys conducted via an online questionnaire. The respondents were either academics or IT industry practitioners working in South Africa. Using a questionnaire as a data-gathering technique and tool involves posing a number of questions that the respondent has to answer within a set format. For the purposes of this study, two types of questionnaire were used: open ended and close ended. While an open-ended question asks a respondent to formulate his/her own answer, a close-ended question has the respondent pick an answer from a given number of options. In view of this, the questionnaires were carefully designed to obtain responses which could help meet the research objectives. To maximise the response rates, an introductory letter was used to explain the purpose of the research and was useful in quelling any fear or anxiety the respondents may have felt in this respect. This enabled the researchers to collect the data quickly. The data were then analysed statistically using a predetermined tool. The study defined six research questions, outlined in the Table 1.

No.	Research question	Source
1	What are the most needed enterprise systems skills for the IT industry?	Literature review
2	Are the SE students and lecturers aware of the enterprise system skills required in the IT industry?	Questionnaire

3	What are the weaknesses of newly hired SE employees?	Questionnaire
4	What enterprise system skills do you think must be possessed by a SE graduate so that you can hire him/her?	Questionnaire
5	How can the SE curriculum in educational institutes be improved?	Questionnaire
6	What skills do IT industries expect to need in the near future?	Questionnaire

*Table 1: The six research questions employed in this study*

South African e-recruitment services were analysed in order to identify the job enterprise system skills most in demand in the IT industry. The results of this survey appear in Section 4.1.

In order to assess software engineering students' awareness of the most in-demand enterprise system skills as regards the IT industry, a questionnaire was designed and distributed electronically to a sample of 100 software engineering students in all software engineering departments of South African universities. In South Africa there are 23 universities, and all of them have a software engineering department at their Information and Communication Technologies (ICT) Faculties. The respondents were selected from among final-year students who are currently working on their graduation projects. The number of responses received for this questionnaire was 92%. The questionnaire consisted of two questions: How much do you think software engineering skills, courses or knowledge areas will help you to join the IT industry? The answer to this question is a measure in the scale range [1-5], where 1 means the student did not gain any benefit from software engineering courses, and 5 means the student gained maximum benefit from such courses. The aim of this question was to assess software engineering students' awareness of the most important courses in their curricula, as they relate to the IT industry.

To compute the importance of each course, according to the students' opinions represented by the answer to Question 1, the following equation was used:

$$\begin{aligned} & \text{Importance of course } x \text{ (student view)} \\ & = \text{number of students scoring 4 or 5 for course } x \\ & \quad \div \text{Total number of students} \end{aligned} \tag{1}$$

This equation means that for each course  $x$  in a student's curriculum, the importance of the course is calculated by dividing the number of students who answered 4 or 5 to this question (and this represents the students who think that this specific course is very important to their career), by the total number of students participated in the survey.

The second question was an open question which asked students to give their opinions on the enterprise system skills, courses or knowledge areas that should be added to their curricula to help them promptly join the IT industry.

To compute the importance of each enterprise system skill or knowledge area that is not included in the software engineering curricula, the following equation was used:

$$\begin{aligned} & \text{Importance of course } x \text{ (student view)} \\ & = \text{number of students mentioned skill } x \text{ in Q2 response} \\ & \quad \div \text{Total number of students} \end{aligned} \tag{2}$$

Similar to the student questionnaire, a new questionnaire was designed and distributed to a sample of 50 software engineering lecturers at the 23 South African universities. The response rate for this questionnaire was 86%.

The questionnaire also contained two questions: The lecturer was asked to attach a measure of importance [1–5] reflecting his/her opinion of each of the courses in the software engineering curricula, regarding its usefulness in the process of helping students join the IT industry.

The second question was open, similar to the students' questionnaire, where lecturers were asked to give their opinion of the enterprise system skills, courses or knowledge areas that should be added to the software engineering curricula, to help software engineering students promptly join the IT industry.

To compute the importance of each course, according to the lecturers' opinions, the following equation was used:

$$\begin{aligned} & \text{Importance of course } x \text{ (lecturer view)} \\ & = \text{number of lecturer scoring 4 or 5 for course } x \\ & \quad \div \text{Total number of lecturers} \end{aligned} \tag{3}$$

To compute the importance of each of the enterprise system skills, courses or knowledge areas that are not included in the software engineering curricula, according to the lecturer's perspective, the following equation was used:

$$\begin{aligned} & \text{Importance of course } x \text{ (lecturer view)} \\ & = \text{number of lecturer mentioned skill } x \text{ in Q2 response} \\ & \quad \div \text{Total number of lecturers} \end{aligned} \tag{4}$$

A third questionnaire was designed and distributed to a sample of 20 IT industry managers. The objective of this questionnaire was to determine

- the weaknesses of newly hired software engineering graduates, according to IT industry managers; and
- what skills IT industries will expect of such graduates in the near future.

The questionnaire comprised the following questions:

- What are the weaknesses of newly hired software engineering employees?
- What enterprise system skills do you think a software engineering graduate must possess, before you hire him/her?
- How do you think the software engineering curriculum in South African universities can be improved?
- What skills will IT industries expect graduates to have in the near future?

In total, 75% of responses were received from IT industry managers. The results are discussed in Section 4.3.

## 4 Results

This section discusses the results obtained in each research question described in Section 3.

### 4.1 Most required enterprise system skills

Based on the analysis of IT-related job listings disclosed in the databases of famous South African e-recruitment services, Table 2 specifies the importance of each enterprise system skill required by the IT industry. The importance column was simply computed by dividing the number of times each enterprise system skill was mentioned in the job listings, with the total number of job listings analysed (750).

The following conclusions can be reached from Table 2:

- Among the skills, ASP.NET has the highest importance, followed by Java, Oracle, C++, SQL and software testing respectively;
- Programming language-related jobs had the highest ratio of the job listings, with an accumulated importance of 73%;
- Among programming language courses, Java had the highest importance (28%), followed by C++ (22%);
- Among database courses, Oracle had the highest importance (24%), followed by SQL (19%);
- Among mobile development courses, Android and iOS had the highest importance (8% and 7% respectively);
- Among web development courses, ASP.NET and PHP had the highest importance (35% and 13% respectively);
- Among the software engineering core courses, software testing had the highest importance with 15% of the job listings.

Knowledge area	Enterprise system skill	Infrequency of job listing	Importance (%)
Programming language	C#	60	8
	Visual basic	75	10
	Python	23	3
	C++	165	22
	Delphi	15	2
	Java	210	28
Database	Oracle	180	24
	SQL	143	19
Mobile development	iOS	53	7
	Android	60	8
	BlackBerry	15	2
	Windows Phone	15	2
Web development	ASP.NET	263	35
	PHP	98	13
	HTML + CSS	30	4
	Share point	23	3
	JavaScript	30	4
	Web service + XML	68	9
Software engineering core courses	Software testing	113	15
	Project management	60	8
	Software design	83	11

	Software requirements	68	9
	Object oriented programming	98	13
	Software architecture	30	4
	Software quality	8	1
	Software modeling	15	2
	Software analysis	15	2
	Software process	15	2
	Software maintenance	23	3
Others	Business intelligence	45	6
	Network management	30	4
	Operating systems	23	3
	ERP	15	2
	Technical support	23	3

*Table 2: Importance of enterprise system skills on job listings analysis (Data collected 15 July 2015)*

## 4.2 Student and lecturer awareness

As mentioned in Section 3, to assess students' and lecturers' awareness of the most needed enterprise system skills as regards the IT industry, two questionnaires were drafted and distributed: one for software engineering students and the other for software engineering lecturers.

The number of responses received from the students totaled 92 (92%), while 43 responses (86%) were received from lecturers.

Question 2 of both questionnaires was used to assess the awareness of software engineering students and lecturers regarding the most needed enterprise system skills in the IT industry.

Table 3 shows the computed percentage for each of the enterprise system skills required by the IT industry that has a significant importance of  $\geq 4\%$  and no coverage by the software engineering curricula, as reported by both students and academic staff in the open question on the questionnaire (Q2). For example, 41% of the students' responses mentioned ASP.NET as a requisite enterprise system skill for joining the industry, while 65% of lecturers mentioned the same enterprise system skill.

Enterprise system skills	Importance	Importance attached by students	Importance attached by lecturer
Python		10%	6%
Delphi		11%	8%
Oracle	24%	65%	74%
iOS	7%	10%	16%
Android	8%	15%	14%
ASP.NET	35%	41%	65%
JavaScript	4%	16%	15%
Web service + XML	9%	15%	17%

*Table 3: Skills with no curriculum coverage, based on students' and lecturers' opinions*

It can be concluded from Table 3 that

- although ASP.NET has the highest importance of the enterprise system skills required by

industry, 65% of the lecturers mentioned this as an important skill in the IT industry. This indicates that lecturers are aware of the importance the IT industry attaches to this enterprise system skill;

- although Oracle has a high importance (24%), the lecturers and students mentioned this as an important skill for joining the software industry, with scores of 74% and 65% respectively. Again, this indicates that lecturers and students are aware of the importance the IT industry attaches to this enterprise system skill;
- although Web development-related skills (such as JavaScript, Web Services and XML) are deemed important for industry (4%–10%), the lecturers and students rated these skills as important for joining the software industry with 15%–17% and 15%–16% respectively;
- students and lecturers respectively attributed 10% and 16% importance to iOS and 15% and 14% respectively to Android.

In Table 4 presents the industry required enterprise system skills that are covered by only one course in the software engineering curricula. The importance of this skill is compared with the importance which students and lecturers respectively attributed to the course covering this skill (see Equation (1) (students) and Equation (3) (lecturers).

For example, SQL has only one equivalent course in the software engineering curriculum of the all universities in South Africa, and industry importance is 19%, importance given by students is 65% and importance given by lecturers is 75%.

Enterprise system skills	Importance	Importance given by students	Importance given by lecturer
C#	8%	50%	74%
Visual basic	10%	60%	70%
C++	22%	40%	84%
Java	28%	58%	94%
SQL	19%	65%	75%
PHP	13%	33%	30%
HTML + CSS	4%	37%	36%
Software Testing	15%	22%	18%
Project management	8%	25%	16%
Software design	11%	16%	14%
Software requirements	9%	18%	12%
Business Intelligence	6%	12%	14%
Networking management	4%	54%	65%

*Table 4: Skills with only one equivalent course with students and lecturers opinions*

It can be concluded from Table 4 that

- although PHP (HTML + CSS), Software testing, Project management, Software design, Software requirements and Business intelligence have a significant importance of between 6% and 15%, students and lecturers gave these skills the least importance, which means both sets of respondents are unaware of the importance of these enterprise system skills when it comes to joining the IT industry;
- both students and lecturers are aware of the importance of the other skills listed in Table 4.

The conclusions drawn from Tables 3 and 4 are that lecturers and students are not fully aware of the important skills required by the IT industry.

### 4.3 IT industry managers' perspectives of the requisite skills

This section focuses on the results obtained after distributing the IT industry managers' questionnaires (see Section 3.2).

Question 1 dealt with the weaknesses of newly hired software engineering employees. The highest proportion of managers mentioned the following weaknesses:

- Lack of practical experience in software development and programming skills;
- Lack of knowledge about applying software engineering lifecycle phases such as requirement, architecture, design, etc.;
- Lack of business communication skills.

Question 2 was concerned with the skills IT industry expected to need in the near future. Managers responded to this question by mentioning the following skills, in descending order of importance:

- Web development tools and technologies such as HTML, JavaScript (HTML + CSS) and ASP.NET;
- Programming languages such as C# and Java;
- Object-oriented programming;
- Operating systems and networks.

For Question 3, which dealt with managers' opinions of the methods that should be deployed to enhance software engineering curricula in South African universities, the following essential recommendations were received:

- Graduation projects can be supervised by IT companies where students can work on real projects, adding standards, business plans and marketing plans;
- Adding more subjects such as game programming, mobile development, e-commerce development and design patterns;
- Improving the practical part of the curriculum;
- Including student industrial attachment in the curricula.

## 5 Discussion

In this section the result obtained in Section 4 are discussed in details, and further comparisons are made between the responses received from students, lecturers and IT industry managers.

From the job listings, Programming language-related jobs gained the highest ratio of job listings, with an accumulated importance of 73%. IT project development requires developers with good programming skills who are able to develop requirements into products. Testers are needed for automation and regression testing.

- Students seem to be unaware of the importance of programming languages, where scores range from 40% to 60%.
- Lecturers seem to be aware of the importance of programming languages, because their scores ranged from 70% to 94%.

ASP.NET was identified as the skill most needed by industry (35% of the job listings). ASP.NET is an open-source server-side web application framework designed for dynamic and professional websites.

- Students seem to be aware of the importance of ASP.NET because 41% mentioned this enterprise system skill when answering Q2 on their questionnaire;
- Lecturers seem to be aware of this skill, because 65% mentioned it as an important requisite for joining the IT industry;
- IT managers also seem to be aware of the importance of ASP.NET because 71% of the responses mentioned it as most required skill.

The second most important enterprise system skills, namely Java, Oracle, C++, SQL, Software testing, PHP, Object-oriented programming and Visual basic scored in the range of 10%–28%, according to the job listings:

- Neither software engineering students nor lecturers seem to be aware of the importance of the Software testing enterprise system skill, because only 22% of students and 18% of lecturers mentioned this skill in their responses. However, both students and lecturers seem to be aware of the other skills in this category, namely Java, Oracle, C++, SQL and Visual basic;
- IT industry managers seem to be aware of the aforementioned skills, 88% regard them as important skills to have, when joining the IT industry.

For the skills that scored an importance of between 4% and 9%, considered here are the skills without software engineering curricula coverage, namely Python, Delphi, iOS, Android, BlackBerry, JavaScript (Web service + XML):

- Software engineering students and lecturers identified the importance of enterprise system skills for joining industry as being less than 18%;
- IT company managers seem to be aware of the importance of these skills (except for Web services, which did not receive a response from managers).

## 6 Conclusions and future work

The main objective of this research was to explore the education and enterprise system skills needed for the successful development of IT projects in South Africa. To achieve this objective, data were collected from different resources:

- Job listings at a reputable South African e-recruitment service;
- Software engineering students at South African universities;
- Software engineering lecturers at South African universities;
- Information technology industry managers.

It was concluded that the software engineering curricula must add two or more courses related to Oracle, Android, JavaScript, Software testing, Web service, XML and iOS, in order to meet the future development needs of IT projects. Students and lecturers seem to be aware of the many software development-related skills that are not included in the curricula, such as iOS, Android, Software testing and ASP.NET, however, both groups of

respondents highlighted the importance of other skills such as Oracle, JavaScript, Web service and XML. IT managers, because they have the relevant experience, are aware of the most needed enterprise system skills, but did not highlight the need for Web services-related skills.

This research recommends the following to collate education and enterprise system skills for the IT industry:

- Adding ASP.NET, iOS, Android, Oracle and Web services skills to software engineering curricula, since future IT projects will most likely look towards mobile application developments;
- Improving the practical part of curricula by adding an internship period. An internship is a structured, credit-bearing work experience in a professional work setting during which the student applies and acquires knowledge and skills. It involves the application of skills learned from a student's degree majors, within an organisational setting. An industrial attachment should challenge the student to examine the values of the organisation involved in the experience, and to assess the student's education as it relates to the industrial attachment. Other benefits of an industrial attachment include: exploring career interests, learning new skills, gaining work experience, developing a professional network and understanding workplace expectations;
- Increasing the awareness of students and lecturers by allowing IT company managers to give lectures and workshops on the skills most in need within the IT industry.

In this research only the responses of software engineering students, lecturers and IT managers were considered. However, future research should aim to understand those areas where IT experts feel they need more or better education, and should focus on how industry can provide information to educational institutions and companies when it comes to planning curricula and training programmes. This research only considered South African universities as part of its case study.

## References

Amiri, A. (2011). An investigation of undergraduate software engineering curriculum: Iranian Universities case study. *International conference on computer science and education*. Singapore City, 3-5 August 2011, 638-644.

Ayofe, A. (2009). Exploration of the gap between computer science curriculum and industrial IT skills requirements. *International journal of computer science and information security*, 4, 1 & 2, pp 1-10.

Bartels, A. (2007). Global information technology spending and investment forecast. *Forrester research*, pp 4-31.

Clancy, T. (2014). *Standish group chaos report*. <http://www.projectsmart.co.uk/docs/chaos-report.pdf> [Last accessed in July 2015].

Institute of Mechanical Engineers. (2013). *Closing the skills gap*. <http://www.imeche.org/docs/default-source/position-statements-education/imeche-skills->

gap-ps.pdf [Last accessed in July 2015].

Kitchenham, B. (2005). An investigation of software engineering curricula. *The journal of systems and software*, 74, pp 325-335. <http://dx.doi.org/10.1016/j.jss.2004.03.016>.

Koong, K. (2002). A study of the demand for information technology professionals in selected internet job portals. *Journal of information systems education*, 13, pp 21-28.

Lethbridge, T. (2000). What knowledge is important to a software professional? *Institute of electrical electronic engineers' computer*, 33, pp 44-50. <http://dx.doi.org/10.1109/2.841783>.

Mieritz, L. (2012). *Gartner survey shows why projects fail*. <http://thisiswhatgoodlookslike.com/2012/06/10/gartner-survey-shows-why-projects-fail/> [Last accessed in July 2015].

The Department of Labour. (2014). *Annual report*. <http://www.labour.gov.za/DOL/downloads/documents/annual-reports/annual-administrative-statistics-of-the-department-of-labour/2014/adminstatsreport2014.pdf> [Last accessed in July 2015].