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Knowledge and Skills Requirements for Software Developer Students

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***Abstract*—**It is widely acknowledged that there is a shortage of software developers, not only in South Africa, but also worldwide. Despite reports on a gap between industry needs and software education, the gap has mostly been explored in quantitative studies. This paper reports on the qualitative data of a mixed method study of the perceptions of professional software developers regarding what topics they learned from their formal education and the importance of these topics to their actual work. The analysis suggests that there is a gap between industry's needs and software development education and the following recommendations are made: 1) Real-life projects must be included in students' education; 2) Soft skills and business skills must be included in curricula; 3) Universities must keep the curriculum up to date; 4) Software development education must be made accessible to a diverse range of students.

***Keywords*—**Software development education, Software industry, IT workforce, Computing curricula.

I. Introduction

SOUTH AFRICA has a shortage of professionals with ICT skills, but this is a worldwide phenomenon [1]. Not only is there a shortage of software development (SD) workers, but Computer Science students are graduating with a lack of skills that companies are searching for [2]. Regarding ICT skills in South Africa, "not all graduates are prepared for the working environment, and don't always fit in. This is a gap that needs addressing." [3]

The SD industry expects students to be educated in courses and projects that are professionally relevant and that prepare them well for the workplace [4]. The results of [5] underlined a looming crisis in several areas: graduates who are not trained in areas that the marketplace is seeking; thin pipeline for specific technical skills; increasing pressure to source IT capability; and lag in university responsiveness to the needs of the marketplace.

With the rapid pace at which technology is changing, and in the light of the shortage of software developers, the present study investigated what are the perceptions of professional software developers regarding what topics they learned from their formal education and the importance of these topics to their actual work. The results could help SD educators and curriculum developers to form a picture of the education of software developers in the eyes of the software industry to incorporate suggestions from the SD industry in their programmes. It can therefore result in relevant software development education and contribute in meeting the demand for software developers.

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II. Conceptual Framework

A. The Student in the Software Development Class

Most students in current SD classes belong to the so-called Net generation, also known as the Millennial Generation or Generation Y. The Net generation (especially people born in the US and Canada from the early 1980s to the late 1990s) is characterized by people who may have never known life without the Internet [6]. Their early and omnipresent exposure to technology has defined their styles, their modes of communication, their learning preferences, their social choices, and their entertainment preferences [7].

Lethbridge [8] analyzed the relevance and depth of the knowledge that software professionals had received as part of their university education and identified a significant mismatch between software education and industry in terms of the knowledge needed by software engineers to meet the industry's requirements. Other researchers reported similar gaps [4], [9]-[14], and for [15] filling those gaps is one of the most critical challenges for SD educators.

Gallagher et al. [16] report that while both technical and nontechnical skills are important, the skills most critical are non-technical skills such as project management, business domain knowledge and relationship skills.

Lee et al. [17] found that IS professionals' competencies change as they gain experience in the workplace and they are required to, and have, higher levels of technical skill in early stages and higher levels of non-technical skills in the later stages of their careers.

Plice et al. [18] found that emphasizing technical topics at the expense of business content may provide short-term benefits in transitioning to the workforce, but it might inhibit career advancement as graduates assume greater managerial responsibilities. Emphasizing communications and teamwork skills while maintaining the existing curriculum balance between business and technical content is indicated as an appropriate strategy to align the IS curriculum with the needs of industry.

B. Software Development Education

Software and technical developments have been remarkable in the last few decades, and continue unabated [19]. Software controls critical systems, pervades business and commerce, and infuses entertainment, communication, and other everyday activities. It has profoundly transformed markets, industries,

and the society in general [20]. Not only is the dependence on software increasing, but the character of software production itself is changing – and with it the demands on software developers [7], [20], [21]. The diversity of software applications requires adaptability in responding to client needs, and the diversity of clients and contexts requires the ability to discriminate among criteria for success. This presents new challenges for the education of software developers [20], [21].

Several studies suggest a gap between the knowledge and skills demanded by the industry and the knowledge and skills gained by graduates of university computing courses. Some studies focused on technical skills whereas others focused on non-technical or soft skills and some studies combined technical and non-technical skills. When Information Systems curricula were analyzed from the perspective of the industry in terms of technical and non-technical knowledge and skills, the following gaps in knowledge and skills were found: problem solving and project management skills, knowledge of business, IT business consultancy, security, end-user computing, soft skills related to core knowledge, knowledge related to leadership, and negotiation or giving presentations [4], [11], [13]. Aasheim [14] found that IT managers place more importance than faculty on issues related to hardware concepts, operating systems, leadership skills or entrepreneurial traits. However, both academics and IT managers rank non-technical skills—interpersonal skills, personal skills, technical skills, organizational skills and work experience—in the same order of importance.

Benamati [9] interviewed thirteen IS executives and he found that programming skills and project management skills are both highly desired and lacking from IS graduates. Other soft skills, such as communications skills, business knowledge, and leadership skills are also desired.

The study of [8] identified gaps in technical knowledge between the education received and the knowledge required from the viewpoint of the software development industry. Lethbridge's survey dealt with professionals with industry experience and found gaps in: HCI/user interfaces, Real-time system design, Software cost estimation, Software metrics, Software reliability and Fault tolerance, and Requirements gathering and analysis. Kitchenham [10] ran a similar study as [8], but with SE graduates and the results were quite different with gaps appearing to relate to Web-based programming, Project management, Configuration and release management, Multimedia, Security and cryptography, and Computer graphics. Both studies found that mathematical topics appear to be taught in more depth than required in the industry. Another similar study was performed by [12] in the Finnish context, but he surveyed three role players namely software developers, professors and lecturers, and master students about the relevance of different matters. His results coincide with [8] and [10] results regarding the excessive importance attached to mathematics-related topics at university, and with [10]'s findings of the increased importance of Web-related subjects and skills in industry. Keilet al. [22] identified 19 skills as being the most critical for IT project managers in (IT) projects and ranked them based on their relative importance. The top five skills identified were leadership, verbal communication skills, scope management, listening skills, and project planning and as they pointed out is the fact that none of the top five skills were technical in nature.

Education for software developers currently emphasizes content inspired by closed-shop mainframe development. It is offered largely in traditional classroom formats. Software developers are now educated in much the same way as they have been for years. However, courses with a primary emphasis on current technology in which most of the knowledge will become obsolete as the technology does are a major challenge in the education of software developers. Pressures arising from the changing character of software and from external pressures on educational institutions will require changes in what we teach software developers and how we teach it [21]. Lethbridge et al. [15] argues that the majority of quality and budgetary issues with software have their root cause in human error or lack of skill. These in turn arise in large part from inadequate education. Therefore improving education should go a long way towards improving software and software practice.

To effectively fill this gap between the knowledge and skills demanded by the industry and the knowledge and skills gained by graduates of university computing courses, it would be necessary, on one hand, to guarantee that the educational programmes provide the knowledge required for the job profiles suggested by industry and also assure that this knowledge is taught in a manner enabling future professionals to correctly tackle the problems that they will face during their professional career [23].

C. Key Challenges for Software Development Education

Shaw [21] and [15] and other researchers identified several key challenges for SD education.

Making Programs Attractive to Appeal to Good Students and Meet Societal Demands

Not only is there a great demand for software developers, but educators of computing disciplines at universities are acutely aware of the enrolment declines that have occurred since 2000. Bright minds are going into other disciplines, and low enrolments result in low levels of hiring of new PhD's, which will restrict the capacity for research in the field [15].

Understanding the Dimensions of the Field to Focus Education Appropriately

Most universities offer undergraduate degrees in computer science, and most provide an extensive selection of software-related courses. These programs typically allow a student to study software design and implementation topics, and they provide a common educational base for entry-level programming positions. The software field does not distinguish well enough among different development roles and education for software developers should prepare students differently for different roles. There are five different kinds of undergraduate degree programs in computing covering computer science, information systems, software engineering,

computer engineering, and information technology for which curricula need to be defined and refined [15], [21].

Communicating Real-World Industrial Practices More Effectively to Students

Educators should focus on the appropriate industry-relevant topics geared towards future needs. A large collective effort should be launched to establish two-way knowledge and skill exchanges with companies from more industrial sectors and with more professionals within these companies. Continued industry–university collaborations will result in joint research and education projects and will keep educational offerings grounded in practice [15].

Defining Curriculum Standards that are Forward-Looking

In an evolving field such as SD, curriculum recommendations are needed that are anticipatory rather than an affirmation of the present. The challenge is a fast response to changes in technology and designing curriculum guidelines for the future, while supporting current practice [5], [15], [21].

Providing Education for Existing Practitioners

In addition to educating new students, the knowledge level of the existing workforce needs to be raised by providing effective means for practitioners to keep their skills current [1], [15], [21].

Making SD Education More Evidence Based

SD education should ensure that what is taught has evidence to support it. It is critical to pay more attention to the success stories in industrial practice by gathering evidence from broad industry groups. Computing education models must be examined with workforce needs in mind [15].

Better Use of Information Technology in Education and Training

Educators in the software field can do better at exploiting technology to support the learning process itself. In local classrooms educators could take better advantage of simulations, game-playing exercises and tutorials embedded in systems that provide information as it is needed [21].

Ensuring that Educators Have the Necessary Background

It is unclear what proportion of those educators teaching core SD courses actually have a deep background in the field. Just as students and curricula have to stay updated in the rapid changing world of technology, so the educators should not stay behind and the knowledge levels of the educators therefore have to be raised [15].

Adjusting to a Variety of Delivery Mechanisms

The trend toward globalization is here to stay and the creative evolution of delivery mechanisms will continue. Distance delivery via a variety of mechanisms is here with creative programs that allow working students almost anywhere to complete many, and in some cases all, of their degree requirements from a distance. Educators need to adjust from the traditional lecture format [21].

III. Methodology / Data Collection

A. Research Design and Participants

This paper reports on the qualitative data of a mixed method study. The study was conducted in South Africa and it aimed and was operationalized to investigate the relevance of SD education for the software industry. In 2013's last quarter 995 professional software developers were contacted via e-mail and were requested to complete the anonymous online survey. The respondents were members of the following groups of the professional networks LinkedIn and MyBroadband: Software and Web Developers in South Africa, SA Developer.NET and C# Developers/Architects. Some of the respondents indicated that they sent the link of the survey to their colleagues for completion. Also, 5 managers at software houses were contacted and they sent the link of the survey to the software developers in their company. The number of usable responses received totaled 214.

B. Data Collection, Instrument and Analysis

A survey was developed and refined and it resulted in a questionnaire with a pool of 132 items and an open-ended question at the end of the questionnaire asking for further comments on the education of software developers. Since this paper only report on the qualitative data, it might not seem necessary to describe the questionnaire, but it sheds more light on the respondents' comments in the open-ended question. The first section of the questionnaire gathered information on the biographic data of the respondents as shown in Table I. The second and third sections both listed the same 66 core software development topics. The second section asked for each of the 66 topics: "How much did you learn about this in your formal education?" and was accompanied by a five-point Likert response scale with 1 (Learned nothing at all) to 5 (Learned in depth; became expert). The third section asked for each of the 66 topics: "How important have the details of this specific material been to you in your career as a software developer?" and was accompanied by a five-point Likert response scale with 1 (No importance) to 5 (Essential).

The qualitative data gathered in the open-ended question at the end of the questionnaire came from 77 of the respondents. Furthermore, there were 21 respondents who felt so strong about the topic that they gave up their anonymity and e-mailed the researcher with more comments and suggestions.

For the analysis of the qualitative data the ATLAS.ti 7.1.4 computer program was used. The data was stored as a hermeneutic unit and coded into themes and subthemes and analyzed for dominant themes. From the data analysis, an overall description of the respondents' experiences and feelings about software development education was created. Since the product of qualitative research is richly descriptive and the purpose is not to generalize [24], the results are presented in the form of quotes from the participant comments. The themes identified were: the knowledge needed by industry; the knowledge not needed by industry; the state of SD education; and suggestions for SD education.

TABLE I
PROFILE OF RESPONDENTS (N=214)

		Number (%) of students
Gender	Male	196 (92%)
	Female	18 (8%)
Age category	18-24	25 (12%)
	25-29	64 (30%)
	30-39	94 (44%)
	40-49	28(13%)
	>=50	3 (1%)
Ethnic background	African/Black	40 (19%)
	White	145 (68%)
	Coloured	11 (5%)
	Indian/Asian	14 (7%)
	Other	4 (2%)
Education	Matric	10 (5%)
	IT degree(s)	104 (49%)
	B.Sc/B.Com	38 (18%)
	Certification	22 (10%)
	National diploma	30 (14%)
	Engineering degree	10 (5%)
Work experience (in years)	0-4	63 (29%)
	5-9	62 (29%)
	10-14	51 (24%)
	15-19	22 (10%)
	20-29	13 (6%)
	>=30	3 (1%)

IV. RESULTS AND DISCUSSION

In this section, we look at the qualitative data that provides us with a rich description of the information obtained and assisting the researchers to discover and gain understanding of the perspectives of the professional software developers regarding the topics they learned from their formal education and the importance of these topics to their actual work.

A. The Knowledge Needed

Respondents felt that students lacked certain general knowledge and skills especially related to the way in which software development takes place in the real world.

- *The common problem is that they have no concept of how real projects are managed, how projects are planned and timings are estimated, and various other things relevant to real world development.*
- *I think future developers need some introduction in the SDLC of the workplace along with something like SCRUM.*
- *More practical exposure, become language &os agnostic -> use best tool for the job.*
- *I think the education should focus on what is used in the industry like Agile and Extreme Programming and software practises (TDD)*
- *Practical SDLC experience in a team setting (systems development projects) is a crucial part of the learning process.*
- *General problem solving should be more of a focus.*
- *They should learn the basic fundamentals and not just the methods to provide quick solutions.*
- *The concepts are far more important (design patterns, algorithms).*
- *Math - calculus/algebra/matrices etc - data structures - algorithms - machine learning!!! Totally beneficial.*
- *Met too many honors degree students that don't grasp object oriented design and design patterns.*

One of the respondents echoed the findings of other researchers [3], [10], [11], [18] regarding the lack of business knowledge. “I wasn't prepared from a business knowledge perspective.” and another respondent commented: “When I first started I had very little idea of how to begin working with an existing codebase & team structures.”

Respondents commented on recent developments and trends and what should be taught to students in order to stay up to date.

- *The Functional Program (immutable) paradigm is taking over. Rather teach interfaces, generics, functions, delegates, lambdas and drum in the basics of stacks, heaps, queues and thread safety etc.*
- *Distributed Systems and Parallel computing are becoming more important now.*
- *SOLID (Uncle Bob), Domain Driven Design (Evans) and Brock - Test Driven Design are really useful.*
- *SOLID is extremely important for writing good, maintainable, testable, extendable code*
- *Database design and development is severely under taught. Strong Knowledge of SQL is paramount and it’s not present.*
- *Ignore too many Mobile technology specific courses (i.e. no iOS, Android, Windows Phone etc) - stick with Web skills. UI design for small devices (and innovative UI design) is valuable.*
- *Get students to become familiar with version control of some kind through assigned projects.*
- *They are learning the wrong technologies for the industry; they should be focusing only on the .NET stack and LAMP stack and mob.*
- *They need to be taught industry relevant languages i.e. C# and proper platforms if they come from JAVA.*

B. The Knowledge Not Needed

Respondents had strong opinions on knowledge and topics that they feel are not important and which topics are over-emphasized.

- *Languages and syntax aren't really important*
- *OO is DYING and Inheritance and Polymorphicism is over emphasized at Varsity!*
- *Mutation of state of objects is no longer a desirable paradigm as it limits parallelism.*
- *Ignore too many Mobile technology specific courses (i.e. no iOS, Android, Windows Phone etc)*
- *Web dev is a fad. Need more hardcore real-time programmers.*
- *They should learn the basic fundamentals and not just the methods to provide quick solutions.*

C. The State of Software Development Education

Some of the respondents were quite negative about the state of SD education.

- *I really feel that the tertiary education system is failing them horribly.*
- *I have been attempting to convince XYZ University to produce more able software developers, but nothing is changing.*
- *I do think there is distinct disconnect between what students are being taught at varsity and what they actually need to know to work in a proper software development house and be useful and productive.*

Not all the respondents were negative about SD education. "*On the plus side, I don't think that their degrees can be considered easy or of little value by any means. They clearly worked very hard to earn those degrees and they do seem to be taught a lot of solid foundational principles that can be built on very easily*".

"*Computer science degrees often don't prepare an individual to go out there and start developing systems from scratch, but it gives them a long term advantage, a broad knowledge and understanding of how they should learn development and what they should try to avoid*."

D. Suggestions for Software Development Education

Respondents offered suggestions to improve SD education which included practical experience for students and keeping the curriculum up to date although the fact that the industry changes at such a rapid pace is acknowledged.

- *Universities should bridge this gap by integrating more experience into curriculum.*
- *The most useful thing that varsities could probably do would be to try and make the material they are teaching the students more current and more in-line with what is actually going on out there. I realise that is incredibly difficult when you are trying to plan a syllabus ahead of time and the industry changes at the pace that ours does, but if you want to improve the marketability of students straight out of varsity, that's what will do it.*
- *Lecturers should be able to teach more up to date skills to students, and open their eyes to possible exposures to methodologies.*

Some respondents felt that, since the industry changes so rapidly, students should rather be taught the foundational and theoretical knowledge of SD.

- *Education should be about important principles and knowledge not what businesses may require at any particular time.*
- *The market has a severe lack of solid theoretical computer science training.*
- *Practical software development skills change rapidly so tertiary institutions should focus on general theory.*

One of the respondents acknowledged the fact that the majorities in South Africa, are the minorities in SD classes and the workplace (also reflected in Table I with only 18% females and 19% African/Black respondents) and called on universities to prioritize diversity. "*Increased diversity within the student body should be a priority for universities*".

Software development education should not only include technical knowledge: "*The education of software developers should emphasize soft skills as much as technical skills.*"

Respondents spoke of a gap that forms after SD students had left the university.

- *No problem with the education. What falls flat is what happens with IT companies after graduation.*
- *A high and consistent standard of education in South Africa is exceptionally difficult to find, especially continuing education.*

It is not uncommon in software development to find people without a computing degree but with a lot of experience-computing classes must be delivered with a variety of methods and to a variety of students.

- *There are opportunities for education institutions to pull in "DIY" students like me into the courses they offer. The Internet has a lot of free information making it easy to build your skills. I think a lot of people see this as an option for training and they ignore the traditional education institutions.*
- *Look at for example Udacity (https://www.udacity.com/) and similar MOOC's. They draw the masses and I think it forces universities to change their approach towards education.*

V. Conclusions

There is a shortage of software developers but there is a gap between the education of software developers and what they actually need to know to work in a proper software development house and be useful and productive.

The rapid pace at which technology is changing often causes the knowledge graduates acquire at university to be outdated. Graduates often lack business knowledge and they lack experience in teamwork, and general practical experience on real-life projects.

The following is recommended to offer relevant software development education in the eyes of the industry:

Real-life projects. Real-life and practical experience must be included in students' education.

Soft skills and business skills. Universities must examine their curriculums to ensure that not only technical, but also soft skills and business skills are included in their curriculums.

Up to date. Universities must attempt to keep the curriculum in pace with the rapid change in technology.

Diversity. SD education must be made accessible to a diverse range of students including minority groups as well as SD workers wanting to continue and expand their education.

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