International Journal of Engineering & Technology, 7 (4.35) (2018) 749-754

International Journal of Engineering & Technology

Website: www.sciencepubco.com/index.php/IJET

Research paper

Towards Development of Software Testing Competency Framework to Empower Software Testers' Profession

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Abstract

Separation of job functions between developers and testers due to enforcement of Software Quality Assurance (SQA) concept in software development has created worldwide demands for highly skillful software testers. This job function separation is to ensure that the systems or applications being developed are transparent at its testing activities. This will eventually lead to better quality of software products that will minimize impact or issues regarding software or system errors, bugs or faults. The aim of this article is to discuss on the current nature of software testing industry for identification of competencies issues or challenges related to software testers. This paper is intended to propose a software testing competency development framework as a job profiling, competencies assessment, training needs and professional career development for software testers. It is targeted that the proposed competency development framework will benefit software tester as individual, public or private agencies as organizations and education institutions as academia.

Keywords: *Competency; Software Quality Assurance (SQA); Software Testers' Competencies; Software Testing; System Development*

1. Introduction

System or application development within Information System (IS) and Software Engineering (SE) fields involve several activities such as identification of problems, requirements gathering, analysis, design, development, testing, implementation, support and maintenance. Testing is one of the activities that is essential in software development to ensure that the system and software developed behave correctly as expected.

Current testing activities in systems development projects are normally conducted at the later stage of system development phases and it can be seen that the individuals or teams that doing the testing are the same personnel who developed the systems or applications. Various research in the field of software testing have suggested for testing to be carried out starting at the initial stage of software development until the final stage of System Development Life Cycle (SDLC). While there is an assumption that software testing should be an automated process that uses tools and techniques for the testing task, there are parts of testing that requires human ability and creativity. Existence and introduction of automatic testing tools in the market are incapable to remove human functions as it needs to be operated, monitored and managed by humans [1]. Choosing which technique or tool is most appropriate for the testing task and to interpret testing process outcomes requires insight and creativity of humans. Testing activities such as verification and validation activities requires human intervention to perform tasks such as reviews, inspections and audits., and therefore, testing activities will be highly dependent on the performance of the involved employees or testers [2].

Software Quality Assurance (SQA) concept has been introduced and enforced in systems development processes to ensure errors, bugs and faults are identified and removed earlier with the least cost. This leads to the enhancement of the traditional waterfall model in systems development with the V- model which requires testing activities at each phase of systems development before starting to the next phase. The traditional waterfall model is a sequential SDLC with output of each stage becomes input for the next stage [3]. This is as shown in Figure 1.

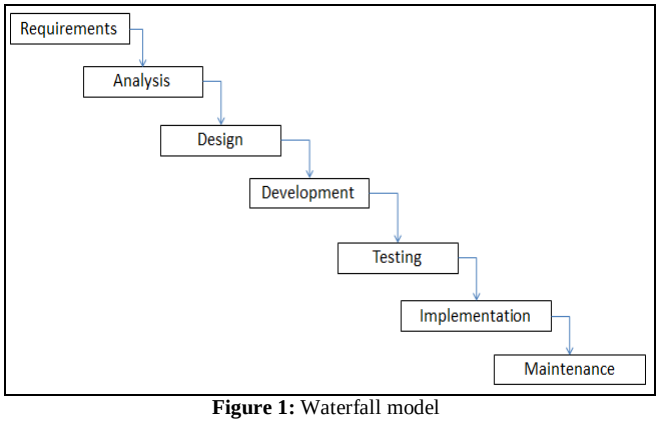


Figure 1: Waterfall model

It can be seen in Figure 1 that testing activities are only conducted upon completion of development phase and tester roles and involvements are only during the testing phase in the waterfall model. Therefore, there is late detection of defects as testers are not involved from the beginning of the project. To eliminate the issue of late defects detection that will impact on the project schedule, cost and quality, a Validation & Verification model (V model) as shown in Figure 2 has been introduced. A V model comprises development steps that are bent upwards with the associated testing activities after the coding phase to form the typical V shape. In this model, testing activities begin at the start of the

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project before coding which resulted in huge saving of project time [4].

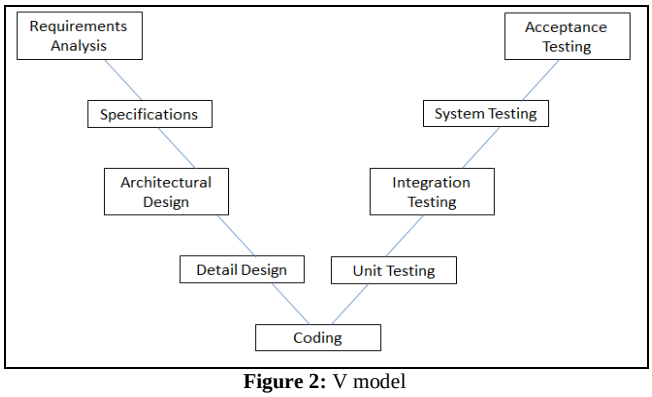


Figure 2: V model

As the testing process is complicated and require detailed and rigorous process, the decision that the testing has completed successfully must be carried out by qualified people. Thus, to ensure efficient and effective testing, it should be conducted by skilled software testers only and not by developers who are the same personnel involved in the system development phase [5]. Testers are responsible to ensure that the software will behave according to the requirements set earlier and with an acceptable level of dependability. Their efforts are crucial to the success of a testing programme that lead to the release of good quality software. Since testers are playing an increasingly important role in software development, the demand for software testers is increasing. To foster the growth of highly competent software testers, there is a need to identify and define the competencies needed for effective software testing. Competency is defined as a set of interrelated knowledge at a certain maturity level or performance benchmarks for successful performing of a working process or a professional activity [6].

Prior research mostly focused on the technical study of software testing such as in the field of web application testing [7, 8], automated software testing [9], Graphical User Interface (GUI) testing [10], software test-code engineering [11] and testing strategies or techniques [12]. However, there are little efforts to establish a formal method for assessing competency levels of software testers. Having the method to assess the competency levels of software testers may help organisations in developing and promoting competencies of the employees in enhancing their careers in software testing. In other words, it will attract highly competent personnel to pursue a career in software testing field and to ensure the career growth of existing software testers. This will eventually leads to more efficient and effective software testing practices that will shorten the software development and maintenance cycles with highly reliable products [13].

The absence of the software testing competencies framework make it difficult to attract IT personnel into software testing area and develop career growth or path among existing software testers especially when testing is often viewed as undesirable and unchallenging profession with few guidelines or criteria to determine the skill effectiveness of the software testers [13]. A survey by Fernández-Sanz, et al. [14] identified several negative factors associated with software testing practices in software companies in Spain such as instability of testers jobs (48%), lack of attractiveness of testing (48%) and poor career growth for testers (41.7%). It has been highlighted that the desired industry profiles for software professionals especially for software testers are not always concise, with different sets of skills required by the industry [15]. The ambiguity regarding the responsibilities of testing positions leads to awareness on the importance on the software tester role [16]. Besides that, the gap between testing skills taught by academic institutions and the testing skills required by the industry will be broadened. According to Chennavajhula [17], the educators are providing superficial knowledge and less focus on testing skills development that subsequently incapable of providing software testers that are equipped with testing skills demanded by the industry. Academic curriculum needs to be revised with in-depth relevant topics on software testing and it is suggested for a formulation of an industry-wide common agreement on the competency framework for testing profession that is agreed and accepted by the software testing industry members.

There exists a gap between recommendations by previous researchers for testing to be conducted by competent individuals with the issue of incompetence of software testers or less competent testers. It has been addressed that competent software testers need to have several skillsets in order for them to ensure that the tested systems or applications fulfill the users' requirements and functioning perfectly without any defect [18]. Therefore, a software testing competency development framework will be proposed upon completion of this research.

2. Related Works

In this section, a brief background on related works pertaining to software testing, competency, competency framework and software testing competency framework based on literature reviews will be discussed.

2.1. Software Testing

Software testing is defined as a test to verify whether the software is functioning correctly as various software related problems are largely caused by lack of effective testing that have brought major problems and financial losses [19]. This definition was further supported by Garousi and Zhi [20] who highlighted that testing will determine the success or failure of the systems development or software project. Software testing involves dynamic verification and validation of program's behavior on a finite set of test cases against the expected behavior [21] that should be supported by a properly defined and controlled testing process which includes activities such as test planning, test case design, test implementation, test execution and test result analysis. It is an important aspect within software quality assurance that is usually conducted for defect detection and reliability estimation [22].

Based on literature surveys, there are many researches on software testing with various aspects being investigated. Garousi and Mäntylä [23] conducted a systematic literature review of literature reviews in software testing and found out that many important areas of software testing such as test management, role of product risk in testing, human factors in software testing, beta testing, exploratory testing, testability, test stopping criteria and test-environment development currently lack secondary studies that are highly important in satisfying industrial and educational needs in software testing. Bertolino [24] addressed software testers' education as one of the challenges in software testing where they should be trained with basic concepts of testing and testing techniques' possibilities and limitations. It was suggested that human potential in software testing needs to be empowered through education and motivation. Beer and Ramler [25] highlighted that tester's knowledge is the ultimate role that contributes to the success of applying software testing methods and techniques.

In 2020, the global software testing services market is expected to be worth US$94 billion (RM379 billion). It has been estimated that the Malaysian software testing services market was worth US$319 million (RM1.29 billion) in 2012 with growth up to US$608 million in 2020 according to the Economic Planning Unit (EPU) Software Testing Roadmap Study 2013 report by International Data Corporation (IDC) [26]. It was reported that the major player in the worldwide software testing services market is the United States of America with 43.8% market share. Meanwhile, Malaysia, India, China and Vietnam are named as the next software testing hub in the Asia Pacific region [27].

Software testers need to be competent enough to enjoy great opportunities in the 13 billion dollar software testing industry as it is predicted that there will be high demand in the domain of software quality assurance and software testing especially on automation testing, performance testing, mobile application testing and security testing [28]. Shortage of qualified software testers will bring several impacts due to improper or insufficient testing such as poor quality of the systems or software being produced, financial losses due to the cost of fixing the defects or bugs. According to Garousi and Zhi [20], it has been reported that 97% of the 800 IT staff from a survey by InformationWeek in April 2002 had problems with software defects and 9 out 10 had been reported being impacted by higher costs and revenue loss due to insufficient testing.

Shortage of skilled personnel for testing in UK, Australia and India is becoming a key challenge and show an increased need for software-testing related training [29]. According to Flinders [30], a survey conducted in December 2009 by a software testing company (Sogeti) in UK revealed that 73% of the 300 respondents said that there is a shortage of software testing skills in the UK and half of them stated that businesses do not spend enough on testing. In 2010, India faced a shortage of 22,000 testers and potentially a shortfall of 40,000 more in the years to come considering the gap between the academia and the training organization to meet the industry's demand [17]. In addition, a Technavio Insights report highlighted that there will be a shortage of 39,000 to 41,000 skilled workers in India software testing services in the next few years [31].

Since 2009, The Malaysia Software Testing Board (MSTB) have been actively organizing and promoting software testing initiatives in Malaysia under the Malaysia Software Testing Hub (MSTH) program. Based on the Eleventh Malaysia Plan (RMK-11), Malaysia will be the next software testing hub with Islamic banking, healthcare, logistics, *halal* industry and education as new economic growth sources. It is the aspiration of Malaysian Government to be able to provide high value software testing services at lower cost, cultivate a local market, raise local flagship companies and build the talent pool of certified and qualified software testers. Besides that, it is targeted that there will be 30,000 certified testers by 2020 that will be able to capture 5% of global software testing market's revenue [32].

2.2. Competency

Competence is defined as the ability to integrate knowledge, skills and attitudes required to carry out certain responsibilities or professional contributions. A competence model is a catalogue that consists of general and technical competences needed and its skill levels such as very high, high, medium or low which are essential for human capital and business process improvements [33]. Competency is a collection of skills, abilities, and attitudes to solve a problem in a given context [34]. Competency models are depicted as descriptive tools for skills, knowledge and abilities characteristics and behaviors identification that are required to efficiently perform a job in a project or within an organization. Figure 3 shows the relation between competences and performance [35].

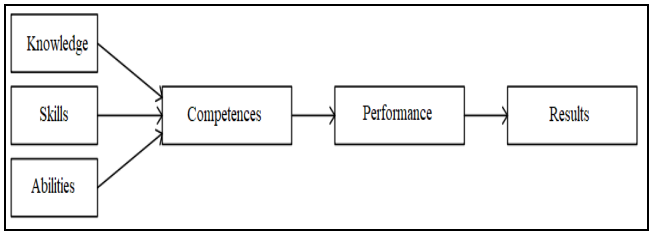


Figure 3: Relations between competences and performance

It can be seen from Figure 3 that competences, which comprise knowledge, skills and abilities will affect the performance of an individual or teams. This will eventually reflect the results or outcome of a specific task or project.

Some of related research on categories of competencies related to software testers is as shown in Table 1.0.

Table 1.0 Category of competencies based on literature review

Competencies Category	Competencies	Source
General	Analysis & synthesis, organization & planning capacity, communication, knowledge of English, information management, decision taking, teamwork, interpersonal relationship ability, self-learning capacity, critical thinking capacity, objectivity & diplomacy, motivation capacity, problem solving capacity, interpersonal conflict resolution among team members, ability to adapt to new situations, ability to work in variety of environments, positive attitude, leadership, creative, commitment to quality.	[33], [13], [36], [35]
Technical	Knowledge about principles and practices in software engineering and software testing, knowing the organizational processes, ability to define, collect and analyze measures, organization & planning capabilities, business knowledge, knowledge & skills for project management, knowledge about testing tools and techniques, technical knowledge (programming, operating systems, databases and testing), knowledge & experience in IT, knowledge about quality issues, knowledge and experience in testing, analytical & learning capability in the areas of project management, requirements analysis, software design, programming, validation & verification tests, configuration management, quality, tests, documentation, maintenance, use of technology	[33], [13], [36], [35], [37], [38]
Social	Interpersonal relations such as communication, adaptability, aptitude to relate, sociability & interpersonal sensibility, cooperation & work in team and handling & solving conflicts.	[37], [38]
Personal	Development in the job environment, personal development and rights & limits	[37], [38]

2.3. Information Technology (IT) Competency Framework

According to Orsoni and Colaco [39], there are three (3) existing UK competency frameworks that are relevant to the IT industry:

a) The Engineering Council UK (2004) - promoted UK-SPEC model
   A framework of competency standards applicable to the broad-based roles related to engineering field. The focus of this framework is on the project management and engineering design competencies with minor overlap of behavioral competencies of IT testers and developers.
b) The Occupational Standards Council for Engineering (OSCE) (2006) – promoted Engineering Competencies Reference Standards (ECRF) model
   This framework identified numeracy, working with others, communication (reading, understanding, writing and speaking) and problem solving as the required behavioral competencies.
c) The Skills Framework for the Information Age (SFIA)
   The UK Government and British Computer Society (BCS)-backed IT skills standard that provides a common reference model for existing IT roles and the needed behavioral and technical skills to perform the roles.

2.4. Software Testing Competency Framework

A competency framework consists of a specific set of knowledge, skills and behaviours or competencies that professionals must have to excel in their careers. It facilitates the identification of training needs and guides the design of professional development programs [37]. Based on the literature reviews, there is little research that focuses on the software testing competency framework. In this paper, two competence model related to software testing will be discussed.

2.4.1. 2006 Certified Software Tester (CSTE) Common Body of Knowledge (CBOK) for the Competency Assessment

Success or effective testing depends on the testers' competency which can be assessed using the 2006 CSTE CBOK Software Testers Competency Assessment. This assessment is administered by the Quality Assurance Institute (www.qaiusa.com) and can be used to evaluate the strengths and weaknesses of an individual software tester. It can serve as a basis for enhancing testers' competencies and to assist in formation of a software testing team or group that has the required competencies to test a specific software project. Besides that, it can be used as a guideline to develop job description or specification for software testers, measuring and evaluating software testers' competencies and formulating a curriculum or training needs to improve software testers' competencies.

2006 CSTE CBOK categorized software testing skills into three categories:

- Not Competent – Indicates a skill that a tester does not have or a skill that a tester does not believe could be used in the process of testing software.
- Competent – Tester has not sufficiently practiced the skill although has learned that skill.
- Fully Competent – Tester understands the skill, know what to do and highly confident to practice it effectively.

The competency score produced by this assessment will be between 1 and 3 as shown in Table 2.

Table 2.0 2006 CSTE CBOK Competency Score

Competency Score	Assessment Result
1	Not competent in software testing
Between 1 and 2	Does not have the basic skills necessary to perform software testing
Between 2 and 3	Can be considered as a software tester.
3	Highly competent in software testing.

2.4.2. Competence Model for Testing Teams

A competence model for testing teams has been formulated by Saldaña-Ramos et al. [33] where it can be used to determine whether testers have the suitable competences to work efficiently, to develop training courses addressed to people who work in testing teams and to assess applicants' resumes and select the most appropriate profiles to participate in testing teams.

The competence levels being used are as follows:

- Low (L) – Team member does not have this competence.
- Medium (M) – Team member is still learning. The competence has been partially acquired.
- High (H) – Team member is autonomous. The competence is totally acquired.
- Very High (VH) – Team member masters the competence and practices it in a stable way.

The definition and design of this competence model is as shown in Figure 4.

However, the application or implementation status of this competence model is unknown or unavailable from the literature reviews.

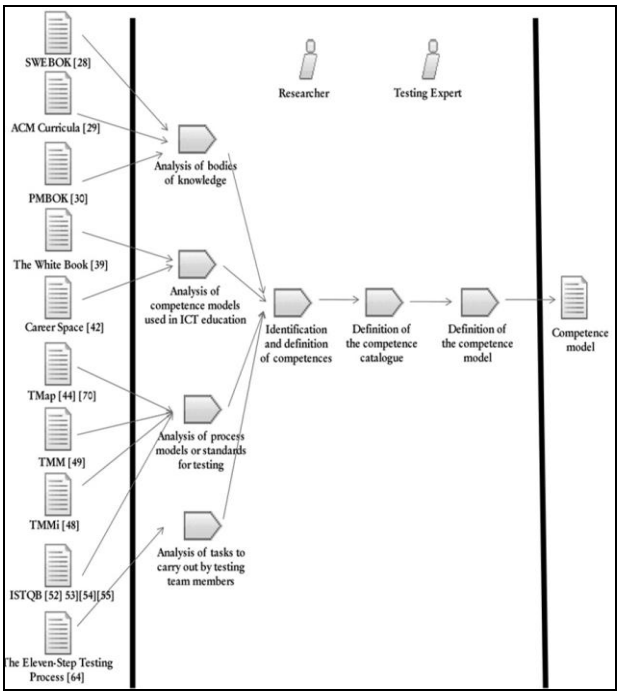


Figure 4: Definition and design of the competence model

3. Methodology

As this research aims to develop a model or framework, it is qualitative in nature where the objective is to find more explanation or detailed description to a specific phenomenon of interest. It is an interpretative research with a deep understanding on issues, challenges and problems encountered by software testers that allows facets of the problems to be defined more realistically. This research will employ an exploratory case study, literature reviews, questionnaire surveys, interviews and document reviews with software testers or IT personnel involved with software testing as the targeted respondents. A pilot study will be conducted before commencement of the actual research to determine the adequacy and relevance of the questions being imposed to the respondents. A conceptual framework together with its implementation and evaluation strategies will be produced upon completion of this research. The research methodology for this research is as shown in Figure 5.

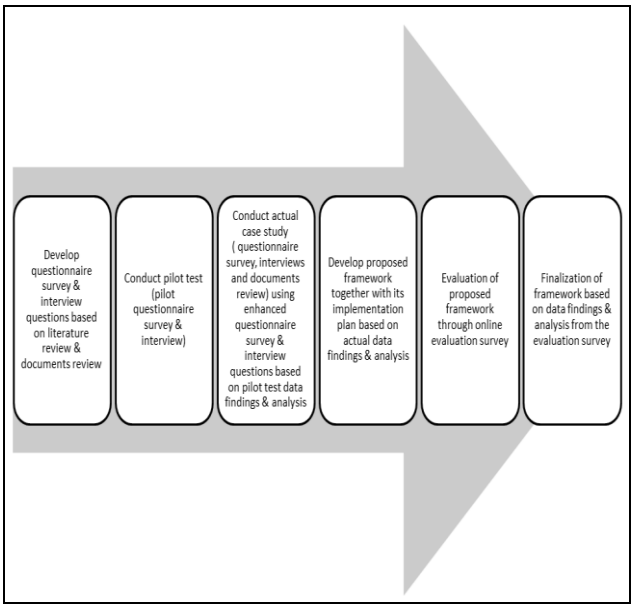


Figure 5: Research Methodology

4. Expected Contribution & Future Works

The importance on the need for software testing competency development framework will indicate the significance of this research to the academia and industry. The list of competencies required from software testers that will be part of the competency development framework could be used as benchmark or checklist while assessing the testers' competencies. The proposed software testing competency development framework will be based on both the software testing activities and on the characteristics or competencies required for a tester to perform those activities. It is targeted that the proposed framework will be able to guide software testers to identify their training needs and to plan for their professional development and for organization to determine their testers' job expectations and career growth and to assist during recruitment and selection process of software testers.

5. Conclusion

In the nutshell, software testers require their own specific competency development framework that will address the required knowledge, skills and abilities from them as testers in order for them to perform efficiently and effectively, either as an individual or as a team. Although there exists several well established and formulated IT-related competency development framework, software testers need to have their own competency development framework as nature of software testing activities are becoming more challenging especially with new technological advancement and high quality demands from the industry.

Acknowledgement

The authors would like to express sincere and heartfelt gratitude to the Public Service Department (PSD) Malaysia for scholarship financing of this research.

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