APPLICATION OF SOFTWARE QUALITY MODELS IN EVALUATION OF STUDY QUALITY

Rudīte Čevere, Sandra Sproģe
Latvia University of Agriculture, Jelgava, Latvia
E-mail: Rudite.Cevere@llu.lv, Sandra.Sproge@llu.lv

Abstract

The analysis and comparison of quality assurance of the development processes, quality models and quality evaluation of the results in software development allows observing a set of similar characteristics through the same concepts in the sphere of education, particularly in the studies of information technologies. Comparison is based on the quality assurance in accordance with the requirements of ISO 9001 standard and Quality Life Cycle Model of software development described in ISO 9126 standard. Similar approach may be applied during the formation of a quality life cycle scheme for the study process and quality model of an education system. A short review of the most popular methods of quality assurance of processes and product quality models used in software development and in education represents the comprehensive attention which has been paid to the quality assurance almost in all spheres of activities for the past years. Involvement of lecturers and students of information technologies in quality evaluation of the study courses is described as part of this process. The review of results and processes which is a well-known method of work in software development can be used in this evaluation. The present paper applies an approach, terminology and the concept of quality from ISO 9001 and ISO 9126 standards.
Key words: *education process, quality model, quality evaluation, software product.*

Introduction

The quality of software products and its assurance has been a topic of interest from the very beginning of programming itself. Step by step greater attention is being paid to different aspects of the quality. Primary the methods and recommendations for coding, testing and implementation were developed which together form the software engineering discipline. It can be characterised as a set of knowledge and methods for the development of effective software. The next stage is connected with the development of software quality assurance methods and frameworks. Quality assurance is based on an assumption that more qualitative and aligned process results in a better quality. However, quality characteristics of the product itself are not discussed in that context. Software product which has no serious defects and therefore is reliable conforms only to the necessary conditions. Hence, it cannot be considered as a comprehensive quality characteristic. The first software quality models were described in 1977 – 1978 and they defined approximately twenty software quality character-

istics. These models were followed by a line of other models where ISO/IEC 9126 was the most remarkable one.

Reviewing software product quality assurance from the process point of view one can see that it includes also the questions of training, qualification, and evaluation of the development staff (ISO 9001). Expanding this aspect further the foundation of the staff qualification can be found in the education process. It means that a study process of information technologies has an indirect impact on the quality of the forthcoming software product. Quality assurance is also an urgent topic in the sphere of education including the application of ISO 9001 standard and development of quality systems and certification of education institutions (Lundquist, 1999; Thonhauser & Passmore, 2006). The analogue approach can be observed in building the quality assurance processes in both spheres. It is prescribed by the essence of ISO 9001 standard. Nevertheless the foundation of quality models allows the presence of different terminology and various approaches. Altogether the review of quality assurance approaches used in the sphere of education and software development reflects the comprehensive attention which has been paid to the quality assurance for the past years. Involvement of lecturers and students of information technologies in quality evaluation of the study courses is described as part of this process. The review of results and processes which is a well-known method of work in software development can be used in this evaluation. The present paper describes quality evaluation of curricula based on an adapted quality model of ISO 9126 standard.

Quality Models and Their Analogy

Quality definitions

Many different quality definitions are used due to the extremely wide application of the quality conception. The most widespread definitions are mentioned below.
In the sphere of software development:
- conformity to the requirements set before (Crosby, 1979; Ishikawa, 1985; Juran, 1988);
- extent up to which a user's needs or expectations are satisfied (Deming, 1988; Feigenbaum, 1983).

In the sphere of education: (Delors, 1996):
- conformity to the aims and tasks of education;
- conformity to the needs and desires of interested parties;
- understanding and support existing on all levels of the education system.

Rauhvargers (2004) from Latvia provides several quality definitions and analyses the application of these definitions in the sphere of education:
- quality as excellence;
- quality as "zero mistakes";
- quality as "compliance with the aim";
- quality as threshold;
- quality as reporting to the society;
- quality as continuous improvement.

According to Rauhvargers only the quality as "zero mistakes" cannot be applied in the sphere of education, since this quality definition is directed to industrial production. Such quality is practically unimplementable in education, while other quality definitions are fully applicable in education. Especially the quality as a continuous improvement is essential for an education institution itself if:

- it has studied all the processes of its activities;
- it has developed procedures for the improvement of each separate process;
- it operates with a strategic view to the future;
- the entire staff is interested in the progression and acts in this direction.

The review of the quality definitions in the sphere of software development and education shows no significant difference between them. All definitions are based on the similar statement of "conformance to something".

Many different methods, standards, models, and methodologies are developed in the sphere of information technologies all over the world (Rozemeijer, 2007), and they are successfully used for the quality assurance and measurement. The aim of the particular research is to use the best practice of information technologies for the improvement and measurement of education quality. Quality model and the metrics for measurement of quality characteristics are necessary for quality evaluation of the software product and the study programme.

Quality models of the software products

Historically many software quality models have been developed and have improved each other. The most popular models are the following:
- McCall's Quality Model;
- Boehm's Quality Model;
- FURPS Quality Model;
- ISO 9126 Quality Model;
- Dromey's Quality Model.

McCall's Quality Model is a model which serves as a basis for many other quality models. All the characteristics of the model are divided into three major directions describing product operation, product revision and product transition. In accordance with these directions a number of characteristics have been defined: maintainability, flexibility and testability for product revision; correctness, reliability, efficiency, integrity, and usability for product operation; and portability, reusability and interoperability for product transition. One of the major contributions of the McCall's model is that it establishes the relationships between quality characteristics and metrics, although there has been criticism that not all metrics are objective. One aspect not considered by this model is the functionality of the software product (Berander, 2005; Al-Qutaish, 2010).

Boehm's Quality Model is similar to the previous model, since it also represents a hierarchical structure of characteristics and sub-characteristics determining the product quality. The characteristics of the top level describe the basic requirements of the application in relation to which the evaluation should be carried out (general utility of the software). The characteristics of the top level give an answer to the three main questions of the software customers:
- As-is usefulness – how easy, safely and effectively is it to use the software?
- Maintainability – how easy is it to understand, to modify and to retest the software?
- Portability – is it possible to use the software if the operation environment has been changed? (Azuma, 2001)

FURPS Quality Model takes into account five characteristics. The first letters of their names form the title of the method - Functionality, Usability, Reliability, Performance, and Supportability. Usage of the FURPS model considers implementation of two steps – setting priorities and defining measurable quality attributes (Berander, 2005; Al-Qutaish, 2010).

ISO 9126 Quality Model is based on the McCall's and the Boehm's models. Development of the software product quality model and quality evaluation standards started in

1986. ISO 9126 defines the product quality as a set of characteristics. Characteristics which are influenced by operation of the product in its planned environment are called the external characteristics. Characteristics which describe the quality of intermediate products of the development process are called the internal characteristics (ISO, 1991).

The Dromey's Model proposed by R. Geoff Dromey is chronologically the latest model. To a certain extent it is similar to the models described before, but Dromey focuses attention to the relations between quality attributes and sub-attributes, and tries to connect features of the software product with quality attributes of the software (Dromey, 1995).

Variety of quality models and included quality attributes have been analysed in many publications (Ortega & Perez & Rojas, 2003), summarising the information about their characteristics and number of usage. All models are based on hierarchically connected set of characteristics and sub-characteristics (in some models they are called attributes). The difference lies in their number (Table 1), names and mutual hierarchy. Some models propose metric for the measurement of quality characteristics.

Table 1.   Number of characteristics defined in models.

| Model	Number of characteristics	Number of sub-characteristics
Boehm's	7	15
McCall's	11	23
FURPS	5	
ISO 9126	6	26
Dromey's	7	7

Comparison of the models shows that the majority of them include six characteristics: efficiency, reliability, maintainability, portability, usability, and functionality; and therefore they may be considered as the most essential for evaluation of software product quality. The same characteristics are defined in the model of internal and external quality described in ISO 9126 standard.

The described quality models show that the definition of quality model has been the same from the very beginning of its development as described in the SQueRE series' standards: "model is a defined set of characteristics, and relationships between them which provides a framework for specifying quality requirements and evaluating quality" (ISO/IEC 25030:2007). Further the authors will base their study on the model defined in ISO 9126 because, as stated by Al-Qutaish (2010) "the ISO 9126-1 quality model is the most useful one since it has been build based on an international consensus and agreement from all the country members of the ISO organisation".

Quality models in education

In the sphere of education quality problems are usually solved on the level of processes, defining the necessary actions and their conformity. The quality of education content has been discussed less. The European Foundation for Quality Management (EFQM) Excellence Model is one of the models used in education institutions. It is a self-assessment framework for measuring the strengths and areas for improvement of an organisation across all of its activities (Osseo-Asare & Longbottom & Murphy, 2005).
The Excellence Model (EFQM) covers nine groups of criteria or modules. Five of them describe the activities of the organisation; the other four cover the results (Figure 1).
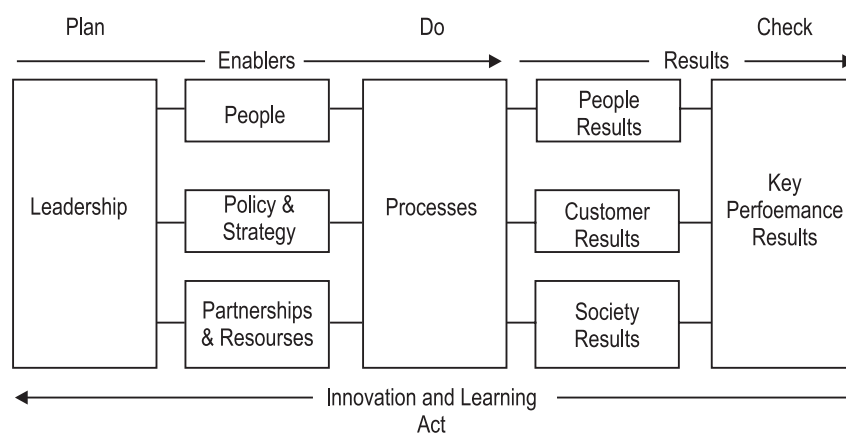
Figure 1.   EFQM model (EFQM, 2009).

An education institution states its plans and goals, performs activities and measures the results. The results are given as a feedback due to which the activities are undertaken to develop new improved plans and organise more valuable actions, thus closing the Deming cycle "Plan, Do, Check, Act". It means that the EFQM model includes all aspects of the education institution and is directed towards a continuous quality improvement.

Internal and external quality assurance standards and guidelines are developed for quality assurance in European Higher Education Area. These standards also envisage external experts – Higher Education Quality Evaluation Agencies.

The mandatory elements of the internal quality management system of an education institution are the following ("Standards and Guidelines", 2005):

- policy and procedures for quality assurance;
- approval, monitoring and periodic review of programmes and awards;
- assessment of students;
- quality assurance of teaching staff;
- learning resources and student support;
- information systems which ensure the information necessary for the effective management of the study programmes;
- public information.

The mandatory elements of the external quality management system of an education institution are the following:

- use of internal quality assurance procedures;
- development of external quality assurance processes;
- criteria for decisions;
- processes fit for purpose;
- reporting;
- follow-up procedures;
- periodic reviews;
- system-wide analyses ("Standards and Guidelines", 2005).

The main responsibility for higher education quality falls upon the higher education institutions. The main task of the external quality evaluation is to inform the society and all interested parties, to ensure reliability on higher education, and to ensure recognition of the diploma.

A great analogy in the sphere of quality evaluation of software products and education results can be observed also in the applied terminology. Usage of "best practices" is recom-

mended, and the internal and external quality is mentioned in both cases. Nevertheless the content of internal and external quality is different. In software development it means the statical and dynamical quality of the product, while in the sphere of education it is connected with the internal activities of institutions and activities of external education institutions.

A comprehensive diagram has been developed in the software quality evaluation standards showing interactions between different quality models and systems (ISO/IEC 25030:2007). By the analogy with it the representation of education system and its quality models is given in Figure 2. In accordance with the standard the quality model serves as a framework to assure that all aspects of the quality are considered from the viewpoints of internal and external quality, and quality in use.
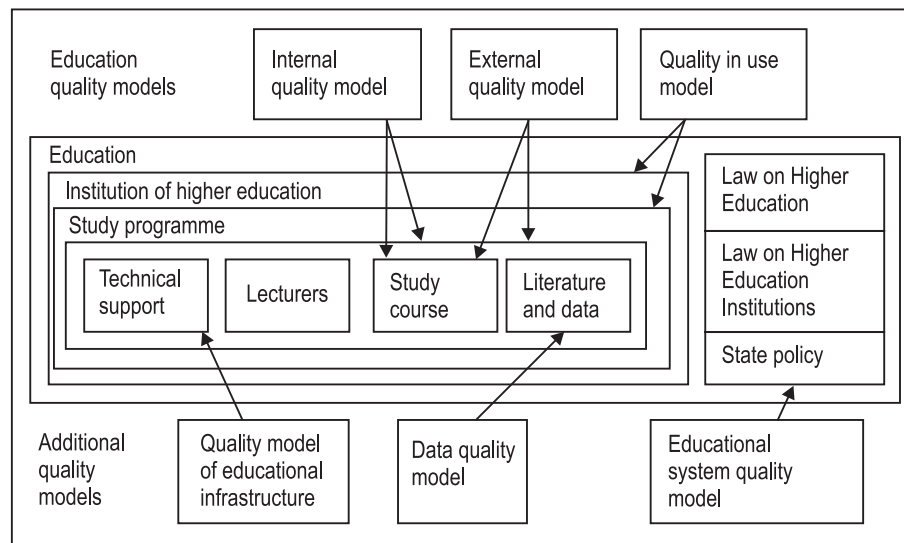
Figure 2.   Model of the education system and quality models.

Discussion

The aim of this paper is to show how the internal and external quality models of the software product (ISO 9126) can be used in the quality evaluation of the information technology study programmes of a higher education institution. For this purpose several characteristics of software product quality have been adapted to the education process.

First of all the research provides an evaluation on the external quality of study courses. The role of evaluators is delegated to the users of these courses, i.e. the students of all years of bachelor studies. The evaluation process encompasses the selection of the characteristics which can be measured by students (Table 3 "Student's evaluation"). Collection of the student's opinion is started with Year 1 students and will be continued at the end of each study term. During the evaluation the students will have to fill in the questionnaire about each course of the particular term. The questionnaire will be repeated till the end of the bachelor study programme. Therefore the process of collection of the measurements will be four years long. During this period the data will be obtained that allows preparing evaluation of the whole study program. The questions asked to the students are prepared with the aim to get the metrics of quality characteristics defined before. Examples of the metrics are given in Table 2.

Table 2.   Examples of the quality metrics of study programme.

Quality characteristics (sub-characteristics)	Metric	Question of the metric
Functionality (functionality compliance)	Compliance of the course	Is the delivered content of study course compliant with the defined content of the course?
Functionality (suitability)	Quality of lectures	Is the quality of lectures good enough?
Functionality (suitability)	Quality of the practical tasks	Is the quality of practical/ laboratory tasks good enough?
Usability (understandability)	Understandability of study course	Is the study course understandable?
Usability (learnability)	Quality of study materials	Is the quality of the materials of lectures/ practical/ laboratory tasks good enough?
Usability (learnability)	Availability of literature	Is the literature necessary for the given courses available?
Usability (understandability)	Understandability of the meaning of the course	Do you understand the meaning of the course?
Portability (co-existence)	Usefulness of the other courses	Is knowledge from the other courses useful for the particular course?
Portability (co-existence)	Redundancy of the information	Does the course contain information delivered in other courses?

The evaluation of the internal quality of study courses made by the experts is being planned in parallel with the evaluation of external quality. The role of experts will be delegated to the lecturers. The number of internal characteristics which can be measured by the expert opinion is greater than the number of characteristics chosen for the external evaluation (Table 3 "Expert's evaluation"). The expert's evaluation should be carried out once during the period of accreditation of the study programme. The full evaluation of the study programme can be obtained combining the evaluations given by the students and the experts.

Table 3. **Adapted ISO 9126 Quality model for the evaluation of a study programme.**

Quality characteristics	Quality sub-characteristics	Evaluators
Are all the required courses included in the study programme?		
Functionality	Suitability Functionality compliance	Student's evaluation
	Accuracy Interoperability Functionality compliance	Expert's evaluation
Is the study programme easy to teach and to learn?		
Usability	Understandability Learnability Deliverability Attractiveness	Student's evaluation
	Usability compliance	Expert's evaluation
How efficient is the study programme?		
Efficiently	Time behaviour Resource utilisation	Student's evaluation
	Efficiently compliance	Expert's evaluation
How easy is it to maintain the study programme?		
Maintainability	Analysability Changeability Stability Verifiability Maintainability compliance	Expert's evaluation
How easy is it to transfer the courses?		
Portability	Co-existence Replaceability	Student's evaluation
	Adaptability Co-existence Replaceability Portability compliance	Expert's evaluation

Conclusions and Proposals

Analysing the quality models of software products the authors found that an analogue quality model can be developed for the study programme of information technologies. The model of the internal and external quality can be applied to the definite study programme. Quality characteristics can be described with metrics which should answer the following general questions:

- Are all elements of the necessary knowledge and skills included in the study programme?
- Is the study programme easy to use (to teach and to learn)?
- How efficient is the study programme?
- How easy is it to modify the study programme?

Quality improvement and assurance in the education institution requires introduction of new control mechanisms and modification of the existing ones. This policy will be efficient only if it has a complex development programme including such components as changes of the existing education legislation, creation of new motivations, and obtaining the new experience. The quality improvement policy as a strategic function includes also training a staff of lecturers to evaluate their own work, and usage of the student's opinion for work improvement. Involvement of the students in the study process quality assurance and quality improvement activities of the university gives the students of information technologies a possibility to acquire practical skills in activities necessary for the software product quality improvement. The study process is not an individual work of separate lecturers, it is a result of collective efforts, and it is more and more necessary to involve the students in it as well as to apply successfully used methods from other branches.

Acknowledgements

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Adviced by Pēteris Rivža, Latvia University of Agriculture, Latvia

Rudīte Čevere	Dr. sc. comp., Assoc. Professor, Head of Department of Computer Systems in Faculty of Information Technologies, Latvia University of Agriculture, Liela Street 2, Jelgava, LV-3001, Latvia. Phone: + 371 63026761. E- mail: Rudite.Cevere@llu.lv Website: http://www.llu.lv/
Sandra Sproģe	Mg. Paed., Latvia University of Agriculture, Liela Street 2, Jelgava, LV-3001, Latvia. Phone: +371 63005668 E- mail: Sandra.Sproge@llu.lv Website: http://www.llu.lv/