

## SOFTWARE DEVELOPMENT QUALITY MODELS IN ENGINEERING EDUCATION

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**Abstract.** Regarding the quality in the development of software products and in engineering education of information technologies, one is unable to speak about an equipollent quality and a single quality model. Quality needs to be evaluated from different points of view, and thus, various objects – processes, intermediate results, and the end products require the assessment. A great experience of quality assurance in the software development has been obtained both on the level of the process quality and the level of the end product quality evaluation. Various quality models of software products and methods of quality evaluation have been developed. Besides the methodical and scientific publications, they are recorded in many international standards of software engineering. A voluminous description of quality requirements, models, and methods is included into the new ISO 25000 series of software standards. The definitions of quality, and approaches of quality assurance and quality improvement as well as the ways for quality understanding and control are usually discussed in the sphere of engineering education. The significance of quality evaluation and the obligation of an education institution to perform quality evaluation regularly has become a frequent topic for discussion; while the requirements of such evaluation and the implementation procedures are not specified yet. The authors of the present paper demonstrate the adaption of the software product quality models for engineering education of information technologies.

**Keywords:** software development quality, quality model, quality standards, engineering education.

### Introduction

Quality assurance, accreditation, and attestation in the European Higher Education Area are mutually connected concepts, since all the three concepts deal with the problem of higher education quality. Accreditation is a warranty of the state to quality of the study programme. Accreditation is a tool for evaluation of the quality concept and its implementation in higher education institutions [1]. It can be defined as a quality evaluation procedure, the aim of which is certification of a study programme or an education institution. Usually it is carried out by an authority independent from the higher education institution. Attestation is already connected with quality, as this procedure confirms quantitative and qualitative characteristics of the study programme on the intermediate level of higher education institutions. Therefore, for the improvement of mobility of the students, one should start with the quality improvement and continuous perfection of it on the level of the study programme.

It is necessary to define the aim and the desired study results (knowledge, skills, and competences) prior to developing and implementing a study programme. The development, evaluation, and quality assurance of study programmes of information technologies are discussed in this paper. Based on the European accreditation criteria and recommendations for study programmes of information technologies [2], graduates of bachelor studies should produce the following study outcomes:

- underlying conceptual basis for informatics;
- analysis, design and implementation;
- technological, methodological and transferable skills;
- other professional competences.

These study results of bachelor study programmes of information technologies recommended by Europe serve as guidelines for maintaining the existing programmes and for development of new ones. In Latvia, professional standards serve as the guidelines for the achievable results during the development of new study programmes. The necessary knowledge is defined in these standards by dividing it into perception, understanding, and skills [3]. Another essential factor relates to the evaluation of the achievement level of these results.

Long-term experience working in the sphere of software development as well as in higher education of information technologies and training specialists allows seeing deep analogy between these two fields. Quality assurance methods have been worked out deeply and voluminously from the very beginning in this sector. Especially great attention to the quality in software engineering has been

paid during the previous twenty years. This allows using best practices of the mentioned experience also in training the specialists of information technologies.

### Materials and methods

Quality assurance in software engineering usually has a systemic approach, drawing attention to different levels, and different involved elements and processes. It is not possible to look on the software product throwing away the system in which the software product operates. Depending on the system size and functional requirements, the particular element may have additional quality requirements, since the elements are related to each other in a conjoint system. Every element of the system imposes its specific quality requirements, which first depend on the viewpoint from which one looks at the system at a certain moment. Single application software may be considered as a system of its own operating in the defined environment, a system may be defined as a regional computer network, involving the particular application software; and the system may be defined as a whole enterprise management system. Therefore, each system consists of elements, yet every separate element may be regarded as a system of its own. In any case, it is necessary to speak about the quality of elements and at the same time about interaction among them.

Each system has a round of stakeholders, and each stakeholder may have its own quality requirements and expectations regarding the system. These requirements can change and can be changed themselves during the life cycle of the system. Stakeholders' desires may be clearly defined or implied, since it is difficult to gather information about the needs and requirement of all stakeholders prior developing of a new software product. Sometimes they appear only when the finished product is operating, but reworking of a finished product can be more time and labour consuming than the development of a new one. Therefore, it is important to gather as much information on stakeholders' desires as possible during the definition of the system requirements. The process of acquiring the system requirements can be divided into two sequential steps:

- the process of definition of stakeholders requirements and needs, comprising the identification of all stated and implied requirements. Hence, the conjoint requirements of all stakeholders are acquired in the result of this process;
- analysis process during which all stakeholders' requirements are analysed and system requirements and constraints are derived as a result.

By analogy with software product, study programmes of engineering education are elements of the higher education institution, which in its turn is an element of the whole system of higher education (Fig. 1). The education system also has many stakeholders with their requirements and needs.

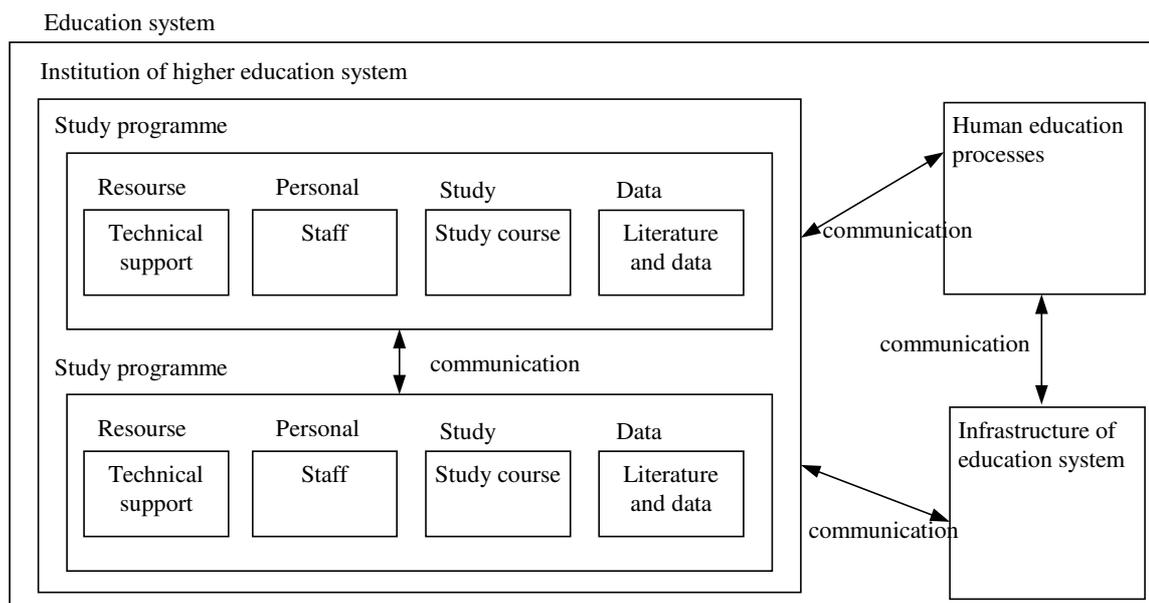


Fig. 1. Model of education system

It is necessary to draw up a quality model and to define quality requirements prior to speaking about the quality of an element or the whole system and performing its evaluation.

Wide range of the society is interested into the results and progress of higher education. Therefore, stakeholders' requirements come from many different sources. Referring to the applied quality model, the software system requirements classification may be used as a model for classification of education system requirements [4]. Figure 2 evidently shows that from such point of view quality requirements of a study programme are a part of its inherent property requirements.

Requirements of education system	Requirements of higher education institution	Requirements of study programme	Inherent property requirements of study programme	Functional requirements		
				Quality requirements of study programme	Quality in use requirements	
					External quality requirements	
			Internal quality requirements			
	Requirements of study programme development	Assigned property requirements of study	Requirements of study fee, study form, study support etc.			
			Requirements of the development process			
Other system requirements	Requirements of education system's infrastructure, literature, data, human business processes etc.					
	Organisational requirements of development					

Fig. 2. Classification of education system requirements

Users and participants of the existing system are the main source of input to the requirements when improving the existing education system and study programmes, or developing new ones. In case of the education system, quality in use is assumed as entering of information technologies specialists the labour market and conformity to employers' needs. The major source of information for these requirements is employers and graduates working in the corresponding field. Requirements in information technologies may vary quite largely among different companies. It is determined primarily by the sphere of activity of a company. A typical scope for IT companies is the development and maintenance of software systems as well as rendering of different IT services. In addition, IT specialists are demanded in many organisations and enterprises basic activity of which is not connected with information technologies. Therefore, it is necessary to develop detailed professional standards or guidelines for probable study results, and carry out regular questionnaires of potential employers alongside with the exploration and definition of stakeholders' requirements.

External quality requirements for study programmes are usually obtained from the current students and graduates as well as legislative regulations. Recently, all decisions and agreements connected with formation of the single European Higher Education Area have become especially significant.

Internal quality requirements come accordingly from the quality in use and external quality requirements, and they are mainly used during the development and upgrade of study courses and programmes, done by the departments and faculties.

## Results and discussion

Many questions ought to be answered in relation with the quality of higher education and its results. What is the quality and what do we mean saying that a study programme is of "high quality"? What is a high quality study programme: a study programme, which is accredited; a study programme, which conforms to the stakeholders' needs; or a study programme graduates, which meet the employers' requirements? However, one can say that the study programme is qualitative, if the study process is well arranged, the necessary infrastructure and staff persist, and the defined study results are achieved both in every study course and the whole study programme. Entering the European Higher

Education Area, the Bologna Declaration recommends moving towards the measurement of study results and competences in order to evaluate the quality of study programmes [5]. Seeing that a study programme is an element of a higher education institution, the interconnections of elements should be taken into account during the definition of its quality model. The quality requirements cannot be viewed in isolation, but they ought to be viewed in the context of other requirements. Further two elements of the education system will be analysed more detailed: a higher education institution and a study programme.

### *Higher education institution*

The task of a higher education institution is to assure progress of study processes and their quality. Figure 3 illustrates a schematic representation of quality management of study processes.

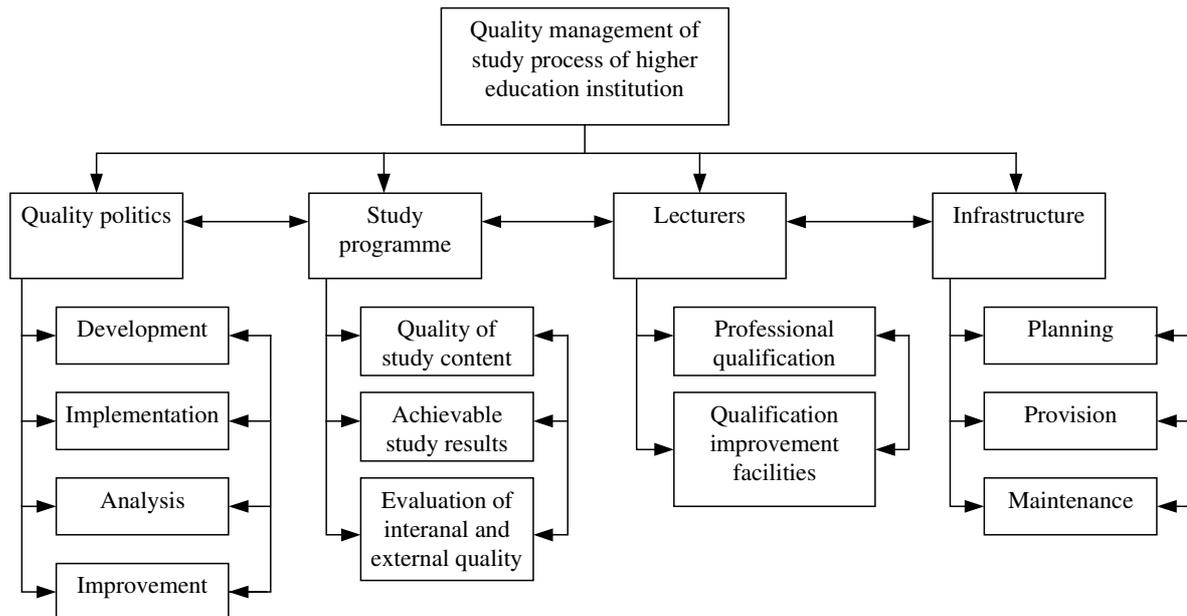


Fig. 3. Scheme of quality management of study processes

Higher education institution is responsible for definition, implementation, and quality evaluation of the study processes. A qualitative process is a precondition for the development of a qualitative product. In many different fields, including the software development, the problems of the process quality are solved considering the requirements of ISO 9001 Quality Standard, and developing quality systems and receiving the certificate for their operation. There have been attempts to develop such quality systems also in the sphere of education; however, they have not proved right [6; 7]. Nevertheless, it is worthwhile to use some aspects of this approach. Higher education institutions should already define the main processes of their operation, appoint a responsible person for each process, and supervise that a sufficient and operative interchange of information between the processes occurs through the time of their running. It is critically important to avoid the growth of causeless documentation amount and variety.

### *Study programme*

The study programme comprises all requirements necessary for obtaining qualification of one academic or professional degree. The study programme is regulated by a specific document – description of the study content and procedure for its implementation. In accordance with the level and type of education, this document prescribes the goals, tasks and planned results of the implementation of the particular study programme; the content of offered education, the amounts of compulsory courses, restricted elective courses and elective courses; the division of time for their acquisition; the criteria for the evaluation of education to be acquired; and the forms and the procedure for testing [8]. The content of education encompassed by the programme has been divided into several study courses. The study course is a layout of the content organised on the defined level, size, and time, which

contains the defined study results. The study course cannot be implemented without a lecturer and help of technical resources of a higher education institution. Separate quality models can be used for each element of the study programme. By analogy with the software product [9; 10], the internal and external quality may be defined for each study course and the whole study programme. Separate evaluation methods should be used for each of these qualities.

The following activities can be used for the quality evaluation of the study programme:

- internal reviews of the content of the study course;
- external evaluation of the study course given by students after the delivery of course;
- summarisation and analysis of the course evaluation results;
- self-evaluation of study programmes;
- publication of self-evaluation results;
- accreditation of study programmes.

The evaluation of study quality should consider that the process quality and the quality of intermediate and end results of various processes are important aspects. For example, qualitatively performed development of a study course, carried out by lecturers and experts having appropriate qualification, which results in the preparation of study course materials complying with the standards, is a precondition of a qualitative study course. However, it does not guarantee a positive outcome. Obtaining a full quality confirmation requires the evaluation of the content. In general, it is a very complicated and time-consuming task for the whole study programme.

Internal quality of a study course means evaluation of the quality of a study course content, used literature and applied data, lecturers, and the necessary technical resources. Quality of technical resources is especially important in engineering education; it requires different devices, equipment, and laboratories.

External quality of study courses characterises the obtained study results and evaluation of the content during the course mastering at the lectures, practical assignments, and laboratory tasks. This evaluation may be done by students involved in the particular study course, and lecturers during specially organised reviews. Reviews are a well-known and efficient method of work in software engineering, which are used for quality improvement of intermediate products and the end product. In essence, they are specially prepared, organised, and managed work meetings. The authors of this paper have developed a method how the reviews should be implemented for the improvement and renewal of study courses in information technologies. The review team for bachelor programmes shall include students of postgraduate and graduate programmes. Their bachelor degree shall be obtained in the same study field, and their recent experience in the role of a student usually gives fresh ideas and effective recommendations for the course improvement. The checklists and additional rules for description of full programmes have been developed for the course reviews [11].

The participation of students in quality assurance has a significant role. The students' engagement in quality assurance is recommended and even required by the Standards and Guidelines of the European Higher Education Area [12]. Quality evaluation of each mastered study course provides significant information on strengths and weaknesses of the course.

Self-evaluation of study programmes annually results in preparing the self-evaluation reports for each accredited study programme. During the development of these reports, the internal assessment of the study programme by the higher education institution is prepared together with the plan of future progress. In Latvia, a single structure for these reports has been defined, and reports shall be openly accessible for all stakeholders.

Accreditation of study programmes, which gives a state guarantee to the quality, is the most formal activity of quality evaluation.

## Conclusions

1. Systemic approach of software engineering to software product development and evaluation is portable and adaptable to preparation of information technology specialists. It is especially important for IT staff, since quality assurance and evaluation will play an important role in their work process after entering the labour market and further developing new software products.

2. The methods, quality models, metrics, and experience of quality assurance and quality evaluation gained in the sphere of software development can be successfully used in the evaluation and improvement of study courses of information technologies.
3. The quality evaluation of the information technologies study programme shall use previously defined achievable study results of the study programme as a point of reference.
4. Achievable study results defined for the study programme serve as guidelines for each study course during the development of its content and defining the study results.
5. Engagement of students in the quality evaluation plays a significant role, since students are direct users of the programme. The obtained feedback facilitates the quality improvement and enhancement.

It is recommended to launch a wide discussion and reach an understanding on several questions, when considering the significance of the development and quality evaluation of higher education. These questions refer to the most significant quality aspects in education; performance of quality evaluation of education institutions; external and internal evaluation of the quality of study programmes; and application of single quality models in the evaluation of education quality.

### Acknowledgements

This research has been supported by the European Social Fund within the project "Support for the Implementation of Doctoral Studies at Latvia University of Agriculture". Agreement No. 2009/0180/1DP/1.1.2.1.2/09/IPIA/VIAA/017.

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