EVALUATION OF QUALITY AND EFFICIENCY IN ENGINEERING EDUCATION STUDY PROGRAMS

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Abstract. Latvia Higher Education Institutions have offered a large number of the study programs. There is often the question about the quality and efficiency of the study programs and their evaluation possibilities. The quality and efficiency of the study program is often associated with the usefulness of financial and technical resources as well as graduate students grades and labour market opportunities for students. Analysis of the study program quality was carried out using the Latvia University of Agriculture engineering science faculties two study period performance indicators. There are different criteria for the evaluation of the study programs, therefore, manual calculations in each case of the selected criteria are quite complex. As a result, software prototype requirements for the study program quality evaluation system were created. One of the directions of the further research is to develop software that performs automatic calculations of the quality and efficiency of the study programs.

Keywords: higher education, inputs, outputs, performance indicators.

Introduction

The quality and efficiency of the study program is often associated with financial and technical resources. Useful study program financial support allows hiring a highly qualified teaching staff, while technical support allows using modern technological solutions during the learning process. Thereby, graduates, who have received high-quality training content with advanced technology support, more likely find a well paid job. There is no universal definition of quality – aspects of quality change depending on which field it is used. In the terms of higher education it means to measure the process.

Harvey and Knight (1996) defined the concept of quality for higher education. The quality was characterized by permanence, goal achieving, and the eligibility of expenditure [1]. The quality of education was identified with the study programs and their provider's characteristics, compliance with the quality standards and execution of the clients' needs. According to the modern approach to quality, it is closely related to such learning outcomes as general knowledge level, general skills and competences [2]. Therefore, quality is only measured at the end of the process when the process has been concluded.

Samar Al-Bagoury [3] defines efficiency as an expression of the success of the production unit in achieving its objectives through the comparison between planned objectives and what has already been achieved. The main idea of quality and efficiency measurements is to find out, if the Higher Education Institutions (HEI) offered service satisfies the consumers. One of the most important principles in any business is the principle of efficiency; where the best possible economic effects (outputs) are attained with as little economic sacrifices as possible (inputs) [4]. Performance indicators are related to improving the methods of production and increasing the levels of output compared with inputs. The evaluation of quality, efficiency and effectiveness can be considered as the relationships between inputs, outputs and outcomes [5].

Over the last decade in investigations about study program evaluation the key issue was the selection of input and output indicators. Inputs and outputs for the evaluation of the study programs conceptually have not changed. Table 1 provides a summary of selected empirical studies from the last decade research articles. The authors for the higher education study program evaluation define the main categories of inputs as financial and material resources, human resources and general background characteristics of the students. The output and outcome indicators are defined as outputs – knowledge, competencies, scores or proportion of graduated students and as outcomes: graduation rates, proportion of students graduated without delay.

It is important when investments allow to reach the highest levels of quality, efficiency and effectiveness. The precise definition of inputs, outputs and outcomes may influence the results. Since manual calculations in each case of the selected variables are complicated, software for calculations is needed. Software architecture involves structured, analyzed and designed components and subsystems, which interact with each other to form the final system model [6].

Table 1

Summary of study program input and output indicators

Input indicators	Output indicators	Reference
Number of academic stuff, other costs	Number ofPhD graduates, bachelor, master students, PhD students	[7]
Ratio of expenditure spent on higher education institutes to GDP (Gross Domestic Product)	Ratio of people with a diploma to the total population and their employment rate.	[8]
Total staff number, teaching staff, research staff	Total number of graduates, coursework graduates, number of research graduates	[9]
Staff to student ratio, percentage of the faculty with associate professors, postgraduate students, research expenditure	Index of research output per person, index of volume of research output an index of the prestige of the Higher Education Institutions.	[10]
Total number of researchers, statutory grant financial resources received from governmental budget	Total number of students, total value of externally acquired funds like funds for R&D work etc., externally granted research projects, number of publications	[11]
Government budget subsidy, number of academic teachers, licenses to award PhD degrees	Number of full-time and PhD students, percentage of: students abroad, international students, students with university and government ministry scholarships	[12]
Data on financial resources, expenditures and academic staff	Total number of graduate students, courses offered, PhD degrees awarded	[13]

The objective of this paper is development of information system requirements for the higher education study program quality, efficiency and effectiveness evaluation.

Materials and methods

For the study program evaluation three faculties of the Latvia University of Agriculture were chosen – Faculty of Information Technologies (IT), Faculty of Engineering (Eng) and Faculty of Environmental and Civil Engineering (ECE). The faculties realize four year study bachelor programs. The data set includes full time students enrolled in 2011/2012, 2012/2013 and graduated accordingly in 2014/2015, 2015/2016 study years, where the following indicators have been selected as:

- inputs – student enrolment data,
- outputs – number of graduated students,
- outcomes – the number of graduated students with average mark higher than 8 or 9 (Table 2).

Table 2

Study program input, output and outcome indicators

Indicator	Study year	Faculty			Total
		IT	Eng	ECE	
Input: the number of enrolled students	2011/2012	91	125	142	358
	2012/2013	83	127	134	344
Output: the number of graduated students	2014/2015	32	77	96	205
	2015/2016	28	59	72	159
Outcome 1: the number of graduated students with average mark >=9	2014/2015	3	0	22	25
	2015/2016	7	4	14	25
Outcome 2: the number of graduated students with average mark >=8	2014/2015	14	11	52	77
	2015/2016	9	19	47	75

The study program performance indicators are quality, efficiency, effectiveness. The quality is described as the output and/or outcome change per unit of time. The total quality of study program is a measure of the change of graduated students or/and a measure of the change of graduation rates. Efficiency is a measurement between selected output/input data and according the proposed definition, efficiency of the study programs is equal with the number of graduated students divided by the number of enrolled students. Effectiveness of the study programs is calculated by the number of graduated students with average mark equal or higher than 9 and/or 8 divided by the number of graduated students.

The Chi-square test of homogeneity was used to analyze the differences between the faculties' efficiency and effectiveness parameters (indicators) and the z-test test to analyze the differences between two years efficiency and effectiveness parameters.

Results and discussion

In the quality terms the output indicator decreased at the faculties and as a result that total number of graduated students in 2015/2016 was 46 less than in 2014/2015. The number of graduated students with average mark equal or higher than 9 has increased for the Information Technologies Faculty and the Faculty of Engineering by 4, but decreased by 8for the Faculty of Environment and Civil Engineering. The number of graduated students with average mark equal or higher than 8 increased by 8only in the Faculty of Engineering, but decreased by 5for the other two faculties. It can be concluded that the total quality of the study programs as a measure of the change of outputs is decreased as well as the total quality of the study programs as a measure of the change of outcomes (Table 3).

Table 3

Quality of study programs

Indicator	Faculty			Total
	IT	Eng	ECE	
Change of outputs	-4	-18	-24	-46
Change of outcomes1	+4	+4	-8	0
Change of outcomes2	-5	+8	-5	-2

At the same time efficiency at the analyzed faculties is decreased. The total efficiency of all faculties in 2015/2016 study year is less by 11.1 % ($p = 0.003$) than in the previous year (Table 4).

Table 4

Efficiency of study programs as the relation of outputs to input, %

Indicator	Study year	Faculty			Total
		IT	Eng	ECE	
Number of graduated students divided by the number of enrolled students	2014/2015	35.2	61.6	67.6	57.3
	2015/2016	33.7	46.5	53.7	46.2

The effectiveness of the Faculty of Environment and Civil Engineering study programs decreased in the case for the graduated students with average mark equal or higher than 9 by 3.5 %and increased for the graduated students with average mark equal or higher than 8 by 11.1 % (Table 5).

Table 5

Effectiveness of study programs as the relation of outcomes to outputs, %

Indicator	Study year	Faculty			Total
		IT	Eng	ECE	
Number of graduated students with average mark >=9 divided by the number of graduated students	2014/2015	9.4	0.0	22.9	12.2
	2015/2016	25.0	6.8	19.4	15.7
Number of graduated students with average mark >=8 divided by the number of graduated students	2014/2015	43.8	14.3	54.2	37.6
	2015/2016	32.1	32.2	65.3	47.1

Effectiveness for the Information Technologies Faculty study programs was opposite – increased for average marks equal or higher than 9 and decreased for average marks equal or higher than 8. At the same time the effectiveness of the Faculty of Engineering study programs increased by 6.8 % (p = 0.020) in the case of average mark equal or higher than 9 and by18.0 % (p = 0.012)average mark equal or higher than 8. The total effectiveness of three faculty programs increased from 12.2 % till 15.7 % in the case of outcome1 and from 37.6 % till 47.1 % in the case of outcome2.

There are researches where the efficiency indicator results and the need of calculation automation have been discussed. All public HEIs were divided into three groups with similar specialization for analyzing of the efficiency in the Czech Republic [7]. T. Réka [8] aimed to determine the relationship between the efficiency of European higher education systems and the degree of state support as well as the family socio-economic background and concluded that the rise of the private contribution to the expenses of higher education is a more effective tool of the enhancement of efficiency in the poorer countries than in the richer ones.

The results of relative efficiency for 33 Faculties of Social Sciences in Poland determine a combination of technologies that allows more results to be achieved with the same inputs [11]. The study of Nazarko Saparauskas presented – Polish Universities of Technology are diversified in regard to the efficiency of their performance. It was demonstrated that there were considerable reserves for efficiency improvement in particular schools [12].

The analysis was performed evaluating three independent groups of HEIs in Portugal: public universities, polytechnics and the faculties of the University of Porto. It was established that the evaluated independent groups of HEIs were inefficient and the same level of outputs could have been achieved by using about 17 % of the resources effectively used in that year [13].

Duan and Deng [9] investigated the performance of thirty-six Australian universities using efficiency, teaching efficiency and research efficiency. The result showed that Australian universities maintain a comparatively high level of efficiency on the overall operation performance and research performance. Around 115 top Chinese HEIs were selected to measure the efficiency. The analyses showed that mean efficiency in Chinese higher education varies between 55 % and 90 %. The significant difference between HEIs is associated with either the geographical location, source of funding or type of university [10].

There is an evident gap in the research in measuring HEI efficiency and a diversity of definitions may be encountered. This is to some extent understandable given the complexity of the educational process and the general lack of relevant information and data [14]. Studied methods for assessing the effectiveness are sensitive, therefore quality data are necessary. Differences in input, output and outcome definitions affect the calculation results. Also a combination of techniques is required to assess the performance indicators [15].

The previous analysis of students' dropout rate in the Latvia University of Agriculture shows the same tendency efficiency of engineering study programs, as the number of graduated students divided by the number of enrolled students [16]. Students' dropout is dependent on the study marks, curricula, year and faculty [17].

When the number of evaluation criteria is increased, manual calculations in each case of the selected variables are complicated and it is necessary to develop the Information system (IS) prototype. Detailed technical and system usage requirements were developed, which should provide high quality, safe and successful operation of the planned IS (Table 6).

For detailed evaluation of the study level calculation can be made in each system level for bachelor, master and PhD study programs. Since the calculations of the possible study program level are different, the data flow diagram is required for the data flow tracking (Fig. 1).

The data flowchart describes how the system is divided into subsystems as well as responsibilities of each subsystem and conceptually describes the software operation phase. The first phase is input/output/outcome data collection from the faculties, the performance indicators of which are planned to calculate. The next phase is input/output/outcome data usage for calculation in the chosen level. The final part is evaluation and interpretation of the results.

Table 6

IS prototype functional requirements

Package	Performance
1. User interface package	Contains classes for each of the forms that the actors use to communicate with the system. Classes exist to support login, maintaining of professor and student information, selecting study programs, submitting evaluation results, maintaining student grade information, closing registration, viewing reports.
2. Evaluation services package	Contains control classes for interfacing with the evaluation system, controlling student, professor registration, and managing the study program performance indicator calculation.
3. Evaluation object package	Includes entity classes for the university information (study programs offering) and boundary classes for the interface with the study program catalog system.

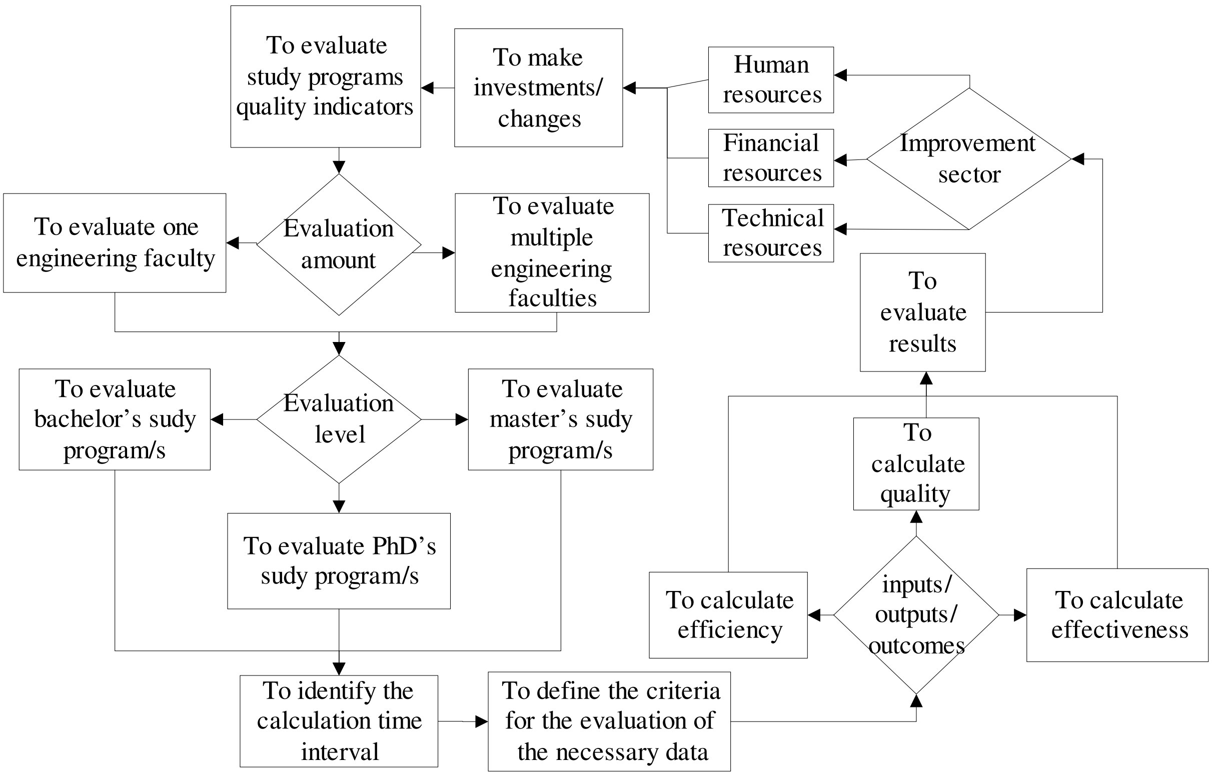

Fig. 1. **Data flowchart**

Conclusions

It was concluded that even if the quality and efficiency of the study programs drop down, effectiveness can be increased. The common tendency for all analyzed programs is that effectiveness has increased by 3.5 % for the average marks equal or higher than 9 and by 9.5 % for the average marks equal or higher than 8. Whereas the total efficiency of all faculties has decreased by 11.1 % and the total quality as a measure of the change of outputs or outcomes has decreased.

It has been shown that there are significant reserves of the performance indicator estimation capabilities. One of the possibilities of improvement is information system development. One of the directions of the further research is to develop software that performs evaluation of the study program quality and efficiency.

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