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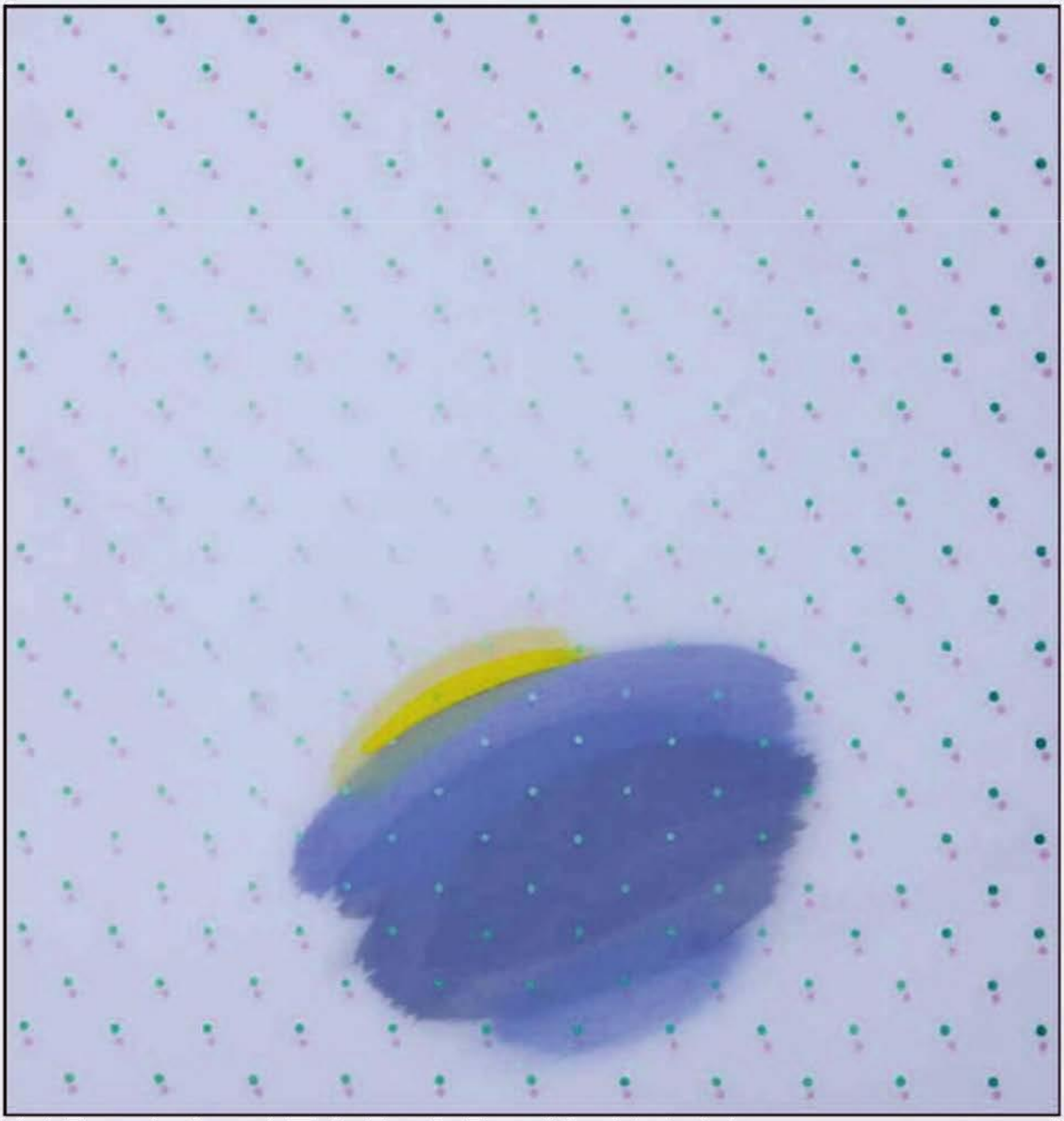

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Mother Teresa University in Skopje, Republic of North Macedonia
Mirce Acev 4, VII floor, Skopje, North Macedonia
Phone: +389 2 3161 004
E-mail: seejsd@unt.edu.mk
Web: www.seejsd.unt.edu.mk

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Evaluation of the methodological aspect of teaching in higher education using MCDM technique*

Riste Timovski†

E-Index department, Goce Delcev University, Stip, Republic of North Macedonia,
riste.timovski@ugd.edu.mk

Tatjana A. Pacemska

Faculty of computer science, Goce Delcev University, Republic of North Macedonia,
tatjana.pacemska@ugd.edu.mk

ABSTRACT

Evaluation processes in higher education towards quality assurance (QA) and quality control is complex process. The pillar that integrates all aspects of evaluation is the study program itself. Before announcement, it is a subject of accreditation process and must answer multiple criteria before approval. After completion of the study program, graduates acquire the qualifications provided within the accredited study program. In order to be as efficient as it is possible, it has to embrace two important aspects in terms of qualifications delivery: what is delivered (what types of qualifications) and how those qualifications are delivered (what methods are used)? The second aspect can be evaluated using optimization technique Analytic Hierarchy Process (AHP), providing unique approach of quality → quantity transition in objective manner, thus enabling data processing and generating readable reports.

KEYWORDS

AHP – Analytic Hierarchy Process, QA –Quality Assurance, EHEA – European Higher Education Area

1 Introduction

There are a lot of different answers, perceptions and definitions regarding the question "What is quality in higher education"? Quality in higher education can be defined as multidimensional construct, simultaneously dynamic and contextual, differently perceived from all the different categories of stakeholders in higher education. And there are multiple stakeholders: providers (HE institutions or Universities), teachers and stuff, students (direct consumers) and others (organizations, agencies, legal aspects, students' organizations, government bodies, trends, media etc.). EHEA obliges the countries to implement quality assurance / control mechanism in their systems as one of the key responsibilities of HEIs. According to the EU legislative, quality assurance involves the systematic review of educational provision to maintain and improve its quality, equity and efficiency. It encompasses school self-evaluation, external evaluation (including inspection), the evaluation of teachers and school leaders and student's assessment. The pillar integrating multiple aspects of evaluation is the study program itself. It is a subject of accreditation process before announcement and must meet multiple criteria before approval. When students graduate and complete the study program, it is expected to acquire the necessary qualifications provided within the study program. Two qualitative aspects in terms of qualification delivery are important:

- What is delivered (what types of qualifications are provided), and
- How those qualifications are delivered (what techniques, methods, methodological approaches are used).

The focus regarding the second aspect is on general principles, pedagogy/methodology and management strategies used during the classes (delivery of the knowledge). In pedagogy terms, it is significant how teachers teach, in theory and in practice. In methodology terms, we speak about the logical scheme based on views, beliefs and values through set of procedures, techniques and approaches that a teacher (group) can develop in order to help students.

The evaluation of the second aspect of a specific study program is done using Analytic Hierarchy Process as Multi Criteria Decision Making technique to detect the level of fulfillment of several specific teaching / methodological criteria by each course within the study program, via unique approach of quality → quantity transition manner. The case study is done on a real study program and students at the end of studying or just graduated, thus having fresh impressions regarding the questions of the evaluations' questionnaires. Networking the importance scale of those criteria with the individual criteria fulfillments of the courses, final form of quality report towards methodological aspect of the study program is generated. The result than can be manipulated for conclusions or used in further data processing, if greater evaluation model is created in terms of quality assurance in higher education.

2 Research activities, techniques and case study

Analytic Hierarchy Process is a structured space technique for organizing and analyzing problems where complex decisions are need to be taken in complex environments, where many variables or criteria are considered in the prioritization and selection of the alternatives or projects. It offers unique approach to make choice of preferences, based on the criteria that are available. AHP transforms the comparisons, which are most often empirical, into numerical values that are further processed and compared. The weight of each factor allows the assessment of each one of the elements inside the defined hierarchy. This capability of converting empirical data into mathematical models is the main distinctive contribution of the AHP technique when contrasted with other comparing techniques. After all the comparisons are made, and the relative weights between each of the criteria to be evaluated have been established, the numerical probability of each alternative is calculated. This probability determines the likelihood that the alternative has to fulfill the expected goal. The higher the probability, the better the chances the alternative has to satisfy the final goal of the portfolio.

AHP hierarchy is consisted of (Figure 1):

- Goal – what is the final aim of the analysis / question to be answered
- Criteria (and sub criteria) – what are the criteria that decisions are depending on, and
- Alternatives – what are the possible alternatives that the best one will be chosen from.

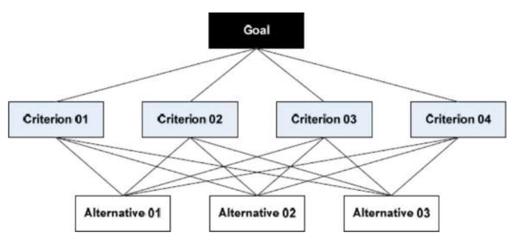

Figure 1. AHP hierarchy (3 level)

Judgement matrix is formed from the pair-wise comparisons of the criteria:

$$A = \begin{bmatrix} 1 & a_{12} & \cdots & a_{1n} \\ a_{21} & 1 & \cdots & a_{2n} \\ \cdots & \cdots & \cdots & \cdots \\ a_{n1} & a_{n2} & \cdots & 1 \end{bmatrix} \quad (1)$$

a_{ij} is a decision-maker value returned for the criteria i and j as a 1-9 value (Table 1), reflecting the preference of the criterion i in relation to criterion j. If i is preferred to j, then $a_{ij} > a_{ji}$. Also, following rules are applied: $a_{ij} = a_{ji}^{-1}$, $a_{ij} > 0$ and $a_{ij} = 1$ for $i = j$. These data are then used in several calculations towards measuring the criteria's weights (importance), consistency check step and overall model synthesis (finding the best alternative).

Table 1: Saaty's preference table

Scale	Compare factor between element i and element j of A
1	Equally important
3	Weakly important
5	Strongly important

7	Very strongly important
9	Extremely important
2,4,6,8	Intermediate values

Normalized matrix $B = [b_{ij}]$ is derived from matrix A, using the method of normalized arithmetic means:

$$b_{ij} = \frac{a_{ij}}{\sum_{i=1}^{n} a_{ij}} \tag{2}$$

The importance values of the criteria are calculated within the vector of criteria's weights $W = [w_i]^T, i = 1, \dots, m$ calculating the arithmetic mean for each row of the matrix B:

$$w_i = \frac{\sum_{i=1}^{n} b_{ij}}{n} \tag{3}$$

The endurance of the model and the final result are based on the consistency check. The weight vector must catisfies the following equation:

$$AW = \lambda_{max} W \tag{4}$$

Maximum Eigenvalue $\lambda_{max} \geq m$ ($\lambda_{max} = m$ for ideally consistent matrix) of the initial pair-wise comparison matrix A can be obtain as it is shown:

$$\lambda_{max} = \frac{1}{n} \sum_{i=1}^{n} \frac{(Aw)_i}{w_i} \tag{5}$$

Then, the consistency check can be performed, calculating the Consistency Index (CI) and Consistency Ratio (CR):

$$CI = \frac{\lambda_{max} - m}{n - 1}, CR = \frac{CI}{RI} \tag{5}$$

RI is the average random index with the value obtained by different orders of the pair – wise comparison matrices (Table 2). If CR ≤ 0.10 (10%), the result is acceptable, meaning the judgement of the decision makers are fine and consistent. If inconsistency is greater than 10%, judgements need to be re-conducted.

Table 2: RI index

N	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**		**9**	**10**
RI	0	0	0,52	0,89	1,11	1,25	1,35	1,40		1,45	1,49

The final step of AHP is synthesis of the data. Matrix of alternatives and criteria $[a_{ij}]$ is constructed, where a_{ij} refers to the quantification (value) of the alternative i regarding to the criterion j (local preference regarding each alternative is denominated). The weights of the alternatives $aw_i, i = 1, \dots, m$ are calculated with summation of normalized elements related to the preferred value of the alternative's columns values, related to each criterion separately:

$$aw_i = \sum_{i=1}^{n} a_{ij} w_i, i = 1, \dots, m \tag{6}$$

Four teaching/methodological aspects were chosen to be evaluated towards overall courses quality:

- Teaching activities in terms of planning, organization and final realization in relation to the needs of the students – Criterion 1;
- Practical work in terms of practical application of the knowledge and the course content / practical examples

delivery through the course – Criterion 2;

- Application of new educational methodologies, tools and techniques (digital and other) – Criterion 3, and
- The possibility to individually work with the teacher – mentoring, supporting and guiding the students – Criterion 4).

Two questionnaires were constructed and conducted, towards gathering the necessary data to be processed using the AHP technique:

- Questionnaire Q1 about the mutual importance relationship of the four criteria / methodological aspects, and
- Questionnaire Q2 about the courses' level of fulfillment of each (out of the four) criteria (contribution in achieving those criteria).

The questionnaire Q1 was constructed towards evaluation of the mutual relationship / importance of the all existing criteria pairs, using the 9-level scale (Table 1). The questionnaire Q2 was constructed towards evaluation of the level of fulfillment of the four criteria by each course of the study program, using the Likert's scale (1 – No fulfillment, 2 – little fulfillment, 3 – Partial fulfillment, 4 – Good fulfillment, 5 – Complete fulfillment).

- Example question: What is the level of fulfillment of the four criteria for the course Databases?
- Example answer: Course: Databases, Criterion 1 – 5, Criterion 2 – 4, Criterion 3 – 3, Criterion 4 – 4.

The evaluation was conduced on a real study program – Computer engineering and technology, First cycle of studies at Goce Delcev University in Stip, NMK. Generations of students enrolled in year 2017 and 2018 were targeted to answer the questionnaires: 23 out of 47 initially enrolled students in 2017, that finished their studies, and 38 out of 37 initially enrolled students in 2018 that had no delay in their study. In total 38 courses were subject of evaluation in total value of 220 ECTS (out of 240 ECTS total for the study program), which is 92% of the total credits' balance of the study program completion.

3 Results and discussion

The first questionnaire results, processed using AHP to derive the relative importance of the criteria, with the weight vector showed in Table 3.

Table 3: Relative importance of the criteria

Criteria	**Priority vector / Criteria weights**
Teaching activities in terms of planning, organization and final realization in relation to the needs of the students	0,12206
Practical work in terms of practical application of the knowledge and the course content / practical examples delivery through the course	0,39905
Application of new educational methodologies, tools and techniques (digital and other)	0,15940
The possibility to individually work with the teacher – mentoring, supporting and guiding the students	0,31949

With analysis of table 3 and the results, it is clear that according to the students, Criterion 2 – Practical work in terms of practical application of the knowledge and the course content / practical examples delivery through the course is most important, with criterion's weight = 0,39905. On the other hand, Criterion 1 – Teaching activities in terms of planning, organization and final realization in relation to the needs of the students is least important, with criterion's weight = 0,12206. It can be seen that both the relative importance indexes of Criterion 2 and Criterion 4 are pretty close, meaning that are complement to each other in the knowledge delivery methodologies and approaches that need to be taken into consideration during the courses. The inconsistency is CI = 0,01026, or 1,02%, meaning that the judgements regarding the importance of the criteria made by the students are more than enough consistent.

The results from the questionnaire 2 regarding to the courses' average criteria' fulfillment levels, as well as the synthesis of the AHP model, producing the final report about the courses' quality regarding the four criteria is generated (Table 4).

Table 4: Model synthesis and final report

Course	Sem	CR1	CR2	CR3	CR4	Priority	Idealized value
Introduction in computer science	1	3,273	3,364	3,045	2,773	0.020620	0.696495
Computer elements	1	2,75	2,611	2,667	2,5	0.017232	0.582056
Mathematics 1	1	4,24	4,042	3,667	4,174	0.026816	0.905775
Programming, basics	1	4,2	4,083	3,625	4,167	0.026835	0.906407
Discrete mathematics	1	***4,583***	4,348	3,87	4,739	0.029311	0.990049
Linear algebra	1	3,842	3,556	3,222	3,333	0.022961	0.775573
Digital logic	2	3,696	3,636	3,409	3,682	0.023991	0.810342
Mathematics 2	2	4,292	4,174	3,864	4,273	0.027624	0.933071
OOP	2	4,52	***4,417***	3,917	***4,792***	0.029606	1
Algebraic structures	2	4,348	4,143	3,818	4,727	0.028501	0.962700
Informatics	2	4,1	3,722	3,778	4	0.025608	0.864979
Computer architecture	3	4	3,474	3,368	4,105	0.024660	0.832961
Software engineering	3	3,826	3,409	3,318	3,409	0.022823	0.770912
Data structures and algorithms	3	4,36	4,083	3,875	4,667	0.028286	0.955437
Probability and statistics	3	4,261	4,13	3,826	4,435	0.027787	0.938583
Graph theory	3	3,895	3,944	3,444	4,222	0.026147	0.883165
Databases	4	4,28	4,292	3,957	4,667	0.028859	0.974775
Visual programming	4	4,083	4,261	4,043	4	0.027298	0.922066
Computer networks	4	4,48	4,417	4,042	4,5	0.029088	0.982527
Operating systems	4	3,72	3,5	3,5	3,826	0.024053	0.812443
Graphics and visualization	5	3,727	3,857	3,905	3,667	0.025092	0.847535
Internet programming	5	4	4,13	3,917	3,708	0.026135	0.882761
Information theory	5	4,095	3,9	3,75	4,4	0.026892	0.908350
Advanced algorithms	5	3,8	3,789	3,368	4,316	0.025778	0.870718
System software	5	4,067	3,929	3,929	4,071	0.026437	0.892963
Digital signal processing	6	4,235	4,133	3,8	4,467	0.027815	0.939515
Microcomputer systems	6	4,1	3,947	3,611	4,158	0.026361	0.890390
Basics of operational research	6	4,095	3,75	3,7	4,2	0.026020	0.878876
Mobile application development	6	4,25	4,286	3,846	3,846	0.026966	0.910824
Artificial intelligence	7	4,389	4,294	3,941	4,471	0.028522	0.963398
E-commerce	7	4,412	4,235	4,063	4,563	0.028708	0.969668
Data management and storage	7	3,929	3,5	3,583	3,833	0.024324	0.821598
Geoinformatics	7	4,133	4,083	3,833	4,25	0.027177	0.917965
Security of computer systems	7	4,222	4,133	4,067	4,313	0.027760	0.937656
Applied software engineering in real environment	7	4,333	4,077	***4,154***	4,615	0.028432	0.960370

Distributed computer systems	8	4,067	4,067	3,615	3,786	0.025866	0.873695
Information systems	8	3,778	3,75	3,75	3,733	0.024827	0.838604
Machine learning	8	4,471	4,267	4,067	4,533	0.028780	0.972125

The course Discrete Mathematics has highest average in terms of Criterion 1: Planning and organization of teaching/ class. The course Object Oriented Programming has highest average in two criteria: Criterion 2: Encouraging practical work / application of knowledge within the courses' content and Criterion 4: Guiding, supporting and/or mentoring students (individual work with the student). Finally, the course Applied software engineering in real environment has highest average in terms of Criterion 3: Application of new educational technologies during the class activities.

The model synthesis / the final report points the course Object Oriented programming as relatively most efficient course towards achieving high levels of the four methodological criteria examined in this research, networking with their relative importance. On the other hand, course Computer Elements is noted as relatively least efficient course regarding the same conditions.

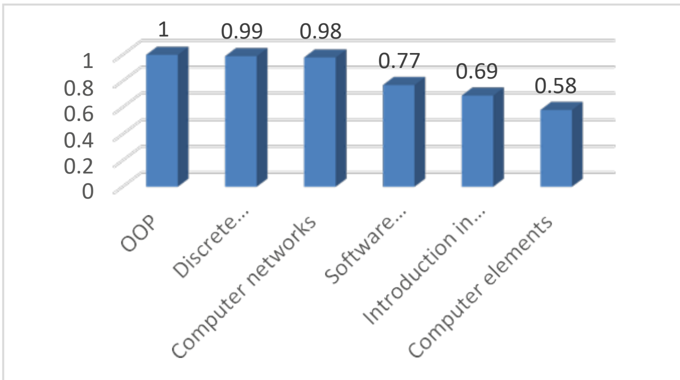

Figure 2. Three most and least efficient courses

4 Conclusion

Given the fact that students assessed Criterion 2 – Practical work in terms of practical application of the knowledge and the course content / practical examples delivery through the course, via AHP processing as most important, it can be concluded that the practical experience level they gain through the study program is crucial, towards their readiness to enter the labor market. Criterion 1 - Teaching activities in terms of planning, organization and final realization in relation to the needs of the students was assessed as least important, meaning that the structure of the practical realization of the course is something not crucial for the knowledge delivery from the perspective of the students. The final report points to the OOP as most efficient course and of course to the least efficient, that need to change the approach and the use of the methodologies regarding the four criteria towards their improvement and using the most efficient courses as reference.

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