12th Research/Expert Conference with International Participation
"QUALITY 2021", Neum, B&H, June 17-19, 2021

SECRET PRINCIPAL VARIABLES FOR QUALITY ASSURANCE IN HIGHER EDUCATION AND SCIENCE

Mile Dželalija and Patricija Nikolaus
University of Split, Faculty of Science, Split, Croatia

ABSTRACT
Quality assurance in higher education and science has a specific role in all countries, giving a base for relevant research and innovation, which all together play a crucial role in supporting social cohesion, economic growth and global competitiveness for individuals and societies. Within this paper we have discussed usual measurable characteristics related to the quality of higher education and science. By analysing the intercorrelations between those characteristics we have discussed a model for discovering secret generalised principal quality assurance variables in higher education and science, as a linear combination of measurable quality characteristics.

Keywords: quality assurance, correlations, eigenvectors, higher education and science

1. INTRODUCTION TO THE QUALITY ASSURANCE IN HIGHER EDUCATION

Higher education represents a system that covers education, research with innovation, and an extension to various needs of the society. By analysis of higher education in developed countries, it is clear that higher education, research and innovation play a crucial role in supporting social cohesion, economic growth and global competitiveness of individuals, and companies, including cultural and socio-economic developments in a country [1]. Quality of higher education and science is crucial for all countries that want to create knowledge-based economy and society. Modern globalising economy requires countries with more and more well-educated individuals who are able to perform complex tasks and adapt rapidly to their changing environment and the evolving needs of the production system.

Innovation in technology is increasingly essential for individuals and companies, which enables also better education systems. Innovation comprises of several measurable characteristics, such as – capacity for innovation, scientific research, spending on research and development, university-industry collaboration, government procurement of advanced products, availability of scientists and engineers, patent applications and intellectual property protection, and similar elements. All those elements of innovation are becoming crucial for quality assurance systems in higher education and science in many countries.

The explosion of various measurable indicators on activities of higher education institution (HEI) and results signals the reality that we all live in a compared, globalised and compared world. In general, countries are designated according to their GDP or any other complex cluster of indicators. Countries and their citizens are also compared on their knowledge economy readiness, ICT use by purpose, global competitiveness, perceived levels of corruption, etc. Comparisons go far beyond the macro level to the level of institutions, airports, banks, universities, schools, and other key institutions [1].

2. QUALITY ASSURANCE IN THE EHEA

Recently in Europe, the main guiding tools for quality assurance in higher education are the Standards and Guidelines for Quality Assurance in the European Higher Education Area (ESG), which were adopted for the first time in 2005. The ESG were revised and adopted in Yerevan in May 2015. Comparing to the first ESG, new ESG involves larger group of stakeholders: European Students' Union (ESU), the European University Association (EUA), the European Association of Institutions in Higher Education (EURASHE) and the European Association for Quality Assurance in Higher Education (ENQA), Business Europe, Education International, and the European Quality Assurance Register for Higher Education (EQAR). This demonstrates that one of main features of quality assurance in Europe is highly stakeholder involvement in development and implementation of quality assurance [2].

In the European Qualifications Framework for lifelong learning (EQF) quality assurance is defined as an essential element to ensure accountability and improvement of higher education and vocational education and training in all EU member states and countries linked to the EU. Thus, the EQF Recommendations sets the common principles for quality assurance, as it is stated in the Annex IV [3], which are consistent with the ESG. The ESG form the basis for admission of quality assurance agencies to the European Quality Assurance Register in Higher Education (EQAR) and the database of accredited institutions and programmes (DEQAR). The ESG provide a clear set of international expectations regarding countries' quality assurance systems.

One important distinction between country on regulations of quality assurance of higher education and science is whether external quality assurance in a country focuses on the quality of study programmes or looks at higher education institutions (HEI) as a whole. In this respect, it is noteworthy that the vast majority of quality assurance systems now focus on a combination of HEIs and study programmes. Some systems focus more exclusively on study programmes, and some focus on HEIs. The picture from self-certification reports in overall suggests that quality assurance systems are becoming more complex and dealing with more information at different levels [4,5,6].

3. QUALITY STANDARDS IN THE ESG

The ESG provides a shared framework for good practice to guarantee the quality of educational activities and research of HEIs, the organisation of quality assurance (QA) agencies' work and activities, and the external evaluation of QA agencies. Standards and guidelines for internal quality assurance covers the following components:

- Policy for quality assurance,
- Design and approval of study programmes,
- Student-centred learning, teaching and assessment,
- Student admission, progression, recognition and certification,
- Teaching staff,
- Learning resources and student support,
- Information management,
- Public information,
- On-going monitoring and periodic review of programmes, and
- Cyclical external quality assurance.

Relevant measurable indicators on quality assurance of HEIs could be displayed in several more-or-less independent characteristics [2]:

- Management of the quality (functional QA system, ethical behaviour and academic integrity, availability of information, etc.).
- Education and student support (relevance of learning outcomes and ECTS allocation,

evidence of student's achievements, stakeholders' involvement, types of teaching activities, transparent admission and continuation criteria, care of student progress, student-centred learning, support of all students, employability of graduates, teachers, library, laboratories, IT, study facilities, financial resources, etc.).
- Scientific research (projects, publications, sustainability, relationship to teaching, etc.)
- Innovation and knowledge transfer, and social engagements (relevance of social role, LLL, social relevance of research, patents, spin-offs, etc.).
- Internationalisation (international projects, foreign students, mobility, etc.).

4. KEY QUALITY INDICATORS

There are various lists of quality indicators in practice in higher education and science. For most of institutions, some of those quality indicators are quite impossible to reach, such as: number of alumni and academic staff winning Nobel Prizes and number of highly cited researchers, articles published in Nature and Science, etc. There is further wide spectrum of indicators on scientific collaborations with other institutions and higher education and industry partners (for example, various world class university rankings).
By the analysis of indicators defined in higher systems in EHEA countries [4,5], the following indicators are most frequent, which are organised here within key missions of HEIs:

- Management of quality:
    - Evaluation of functional internal quality assurance system,
    - Evaluation of ethical behaviour and academic integrity,
    - Evaluation of availability of information,
- Education and student support:
    - Expenditure on teaching per student,
    - Student to academic staff ratio,
    - Facilities at HEIs (computers, laboratories, libraries, etc.),
    - Qualification of academic staff,
    - Quality of study programmes,
    - Inclusion of work experience,
    - Quality of teaching and assessment,
    - Evaluation of support by teachers,
    - Evaluation of social climate,
    - Relative time spent to graduation,
    - Rate of graduation,
    - Rate of graduate unemployment.
- Scientific research:
    - Expenditure on scientific research and art per academic staff,
    - Research and art-related publication output (and sources) per academic staff,
    - Number of registered patents and innovative solutions per academic staff,
    - Number of international scientific research programmes and projects per academic staff,
    - External research income from scientific research within national and international scientific-research programmes and projects per academic staff,
    - Citation index (and sources),
    - Number of post-doc positions in relation to number of PhD completed (and/or per academic/scientific staff),
    - Relevant international prizes won to academic/scientific staff ratio.
- Innovation, knowledge transfer, and social engagements:
    - Size of the Technology Transfer Offices to academic/scientific staff ratio,
    - Incentives for knowledge exchange to academic/scientific staff ratio,

    - University-industry joint research publications,
    - Third party funding,
    - Evaluation of courses offered for Continuous professional development,
    - Spin-offs to academic/scientific staff ratio,
    - License agreements and income,
    - Realised patents and innovative solutions,
    - Student internships in enterprises to student ratio,
    - Co-operations of higher education/scientific institutions with business,
    - Total time participation in LLL of employed and unemployed people,
    - Projects and activities with NGOs,
    - Summer schools for various users.
- Internationalisation:
    - Education programmes in foreign languages,
    - Number of joint degree programmes,
    - Evaluation of opportunities to study abroad,
    - Number of foreign students,
    - Number of students sent out on exchange,
    - Number of academic/scientific staff that realise outgoing mobility,
    - International academic/scientific staff ratio that realise upcoming mobility,
    - Regional co-publications,
    - Number of international doctorate graduation,
    - Graduates working in the Region,
    - Realised grants from international scientific research programmes and projects.

5. POTENTIAL ISSUES FOR QUALITY INDICATORS

There are some potential issues regarding quality indicators in higher education and science. Quality indicators can hardly cover all activities and outcomes of HEIs, which means that there are positive and negative statements on indicators and how to measure them. On the positive side, quality indicators address the growing demand for accessibility, manageably packaged and relatively simple information on the quality of HEIs. This demand is greatly fuelled by the need to make informed choices of HEIs, within a context of massification of higher education and growing diversity of providers and qualifications. Students use the information on indicators to choose where to study. But indicators are not and should not be used as the sole source of information that guides decisions pertaining to the relevance of HEIs. Quality indicators have also encouraged transparency of information and accountability. The system, if using such pure indicators, can draw HEIs attention away from education and social responsibility towards pure very focused scientific research. Another criticism on indicators is that they divert resources from building world-class higher education systems towards building world-class HEIs.

Critiques for quality indicators are based on various aspects, from methodological, pragmatic, moral to philosophical concerns. Indicators on success of HEIs should not be simple as a league table in sports, where outcomes are based on one dimension. In short, critiques for indicators on HEIs success and quality refer to various elements, such as:

- Selection of indicators and their validity. Very often, there are not harmonisations between – what is relevant and important, and – what can be measured.
- Availability of data. There is a serious problem of available statistical information. Teaching quality usually is excluded because it is difficult, expensive and time-consuming to get relevant data.
- Combinations of indicators were not justified. Indicators were combined into the final index in the way they were without theoretical base. There is no rationale for weighting

of indicators. For example, why the weight for proportion of international students could be 5%, but not 10% or 2%, or any other percentage.

- Building competition between HEIs is not always good idea. Because of some importance of indicators, HEIs could decide not to collaborate with other specific HEIs. Thus, in such cases students and the entire society could suffer.

6. THEORETICAL MODEL FOR PRINCIPAL QUALITY ASSURANCE VARIABLES

Higher education and science represent a highly complex system, which integrates various interacting subunits. The relationship of subunits has an effect to the entire system defining collective behaviours of that system, which further defines interrelationships with the environment of the system. Higher education as a complex system has its quality indicators that can describe some parts of the system. Some of those indicators are independent from others, but some of them have strong mutual correlations. It means that not all those measurable indicators can represent its own dimension of the system. The question that should be set here is – "*How to find a minimal and simple set of principal variables that can fully describe the state of higher education system and give information on the quality of the system*?".

The base for key understanding of a complex system we can find in the linear algebra which is fully used and developed various fields of sciences, such as in quantum physics. The key tool for description of any complex system is to find eigenvectors and eigenvalues of a defined system operator. This method provides unique solution, which means that all original data on various indicators can be reconstructed and uniquely represented as linear representations of eigenvectors. The equation for determination of principal eigenvectors and eigen values can be written as [7]:

$$\hat{S}\vec{\psi}_i = s_i\vec{\psi}_i. \qquad \text{... (1)}$$

In the above equation $\vec{\psi}_i$ represents eigenvectors, and s_i eigenvalues when the system is described by the correlation matrix $\hat{S}$. Eigenvalues represent the importance of related eigenvectors in the system. The correlation matrix can be expressed by its correlation elements (as a measure of correlation between any two measurable indicators):

$$\hat{S} = \begin{bmatrix} S_{11} & \dots & S_{1n} \\ \dots & \dots & \dots \\ S_{n1} & \dots & S_{nn} \end{bmatrix}. \qquad \text{... (2)}$$

In many fields of sciences there are well-known statistical method for determination of correlation between variables and finding principal variables (Principal component analysis) by using traditional and outdated Pearson correlation coefficient, which measure only linear correlation between two variables, thus, missing to identify other types of correlations [8].

Contrary, the general expression of mutual correlations between two variables is by mutual entropy, which measures the information that is shared by two variables (*X* and *Y*) [9].

$$S_{ij} = S(X;Y) = \sum_{y\in Y}\sum_{x\in X} p_{(X,Y)}(x,y)\log\left(\frac{p_{(X,Y)}(x,y)}{p_{(X)}(x)p_{(Y)}(y)}\right), \qquad \text{... (3)}$$

where $p_{(X,Y)}(x,y)$ represents joint probability, and $p_{(X)}(x), p_{(Y)}(y)$ marginal probabilities.

Mutual entropy is one of key theoretical concept in the Information theory, which measures any type of mutual dependence between the two variables, and not only linear dependence (which is just first, in some acasen enough well, approximation). The mutual entropy represents general concept which can be used to any complex system which is possible to represent by any type of numerical values. It can be used to biological systems, eco systems, economy, sport and any social activities, such as education and scientific research.

7. CONCLUSION

In this paper we have discussed the most frequent measurable quality indicators in higher education and scientific research, and issues related to the choice of indicators and their weights when representing the quality assurance. We have further discussed a theoretical base for determination of generalised principal quality variables by using mutual entropy between numerical indicators.

Ad hoc decision on combination of indicators and their weights were not enough justified in the existing methodology on quality of HEIs, their rankings and functions of quality assurance mechanisms. Thus, a relevant model can bring theoretical base and scientific support on quality indicators and their combinations. The model can help governance of HEIs and the whole system in order to follow the change of principal variables and their related eigenvalues by time – and how they are related to specific interests, for example only to employability, or student support.

The next steps we plan in our research on principal variables is to test and implement the model to higher education systems in various countries. By analysing data from HEIs, the model allows to discover the principal quality variables as a combination of relevant measurable quality indicators.

6. ACKNOWLADGEMENT

This research was partially supported under the project STIM – REI, Contract Number: KK.01.1.1.01.0003, a project funded by the European Union through the European Regional Development Fund – the Operational Programme Competitiveness and Cohesion 2014-2020 (KK.01.1.1.01).

7. REFERENCES

[1] World Economic Forum, Global Competitiveness Reports 2005-2021, https://www.weforum.org/reports

[2] European Standards and Guidelines for Quality Assurance in the European Higher Education Area (ESG), https://www.eqar.eu/assets/uploads/2018/04/ESG_2015.pdf

[3] European Qualifications Framework for lifelong learning, EC, https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=celex:32017H0615(01)

[4] QF-EHEA Self-certification reports, https://www.ehea.info

[5] EQF Referencing reports, https://ec.europa.eu/ploteus/documentation

[6] M. Dželalija and B. Maguire, Study of self-certification reports on the compatibility of NQFs with QF-EHEA, Council of Europe, 2015.

[7] Any university book on Quantum Mechanics.

[8] Weaver, F.; et a.: An Introduction to Statistical Analysis in Research, Wiley, ISBN: 9781119299684, 2017.

[9] Gray, R.: Entropy and Information Theory, Springer, ISBN: 9780387973715, 2014.