Data Science Systems supporting Continuous Quality Improvement of the scientific institutions pursuing Excellent Science – *Science Wizard* case study of the Research Intelligence

Authors' Contribution:
A Study Design
B Data Collection
C Statistical Analysis
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Abstract

Institution management, regardless of its profile, relies on some information gathered from diffused sources, with a need to support its decisions. Despite the dynamic development of modern technology, managers struggle daily with an information overload, a rapid increase in their number, derangement or regulations which are constantly changing. As a consequence and despite a large number of data, they still have the fragmentary knowledge and rely on intuition or promptings. Similarly, a scientific institution faces challenges on a scientific, social and economic ground. Nowadays, decisions concerning scientific activities may also constitute both opportunities and challenges. Competitive advantage is gained by those institutions which have strategic analysis departments or cooperate with data science professionals that may streamline the operation, rationalise decision-making process and affect strategic outcomes to achieve success.

Key words: Academy of Physical Education • evaluation • Impact Factor • law on higher education 2.0 • public engagement • research evaluation • scientometrics • scientific excellence • sports science

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INTRODUCTION

Institution management, regardless of its profile, relies on some information gathered from diffused sources, with a need to support its decisions. Despite the dynamic development of modern technology, managers struggle daily with an information overload, a rapid increase in their number, derangement or regulations which are constantly changing. As a consequence and despite a large number of data, they still have the fragmentary knowledge and rely on intuition or promptings. Similarly, a scientific institution faces challenges on a scientific, social and economic ground. Nowadays, decisions concerning scientific activities may also constitute both opportunities and challenges. Competitive advantage is gained by those institutions which have strategic analysis departments or cooperate with data science professionals that may streamline the operation, rationalise decision-making process and affect strategic outcomes to achieve success [1, 2].

That is why universities are more and more frequently opting for Business Intelligence systems. However, this constantly changing environment needs also Data Science, which delivers strategic and analytic information, and offers an opportunity to plan and even to predict some areas, i.e. to optimise the structure of an institution and its influence on the productivity, to build the path of scientific activity and its influence on the qualitative effects, etc. Such technology and innovative institution management have already been applied by Polish physical education higher schools, which are dynamically changing and developing.

The article presents practical experience gained in the course of the institutional evaluation of scientific units in Poland, as well as the daily struggle of the scientific institutions with gathering, analysing, interpreting, inputting the data for assessment in line with the governmental regulations. These data were acquired in 2010-2013 in cooperation with the Polish Ministry of Science and Higher Education and the Committee on Evaluation of Scientific Units and 2014-2017 in cooperation with several scientific institutions in Poland (all types from each scientific area). The article focuses on selected higher schools of physical education.

The aim of the paper is knowledge about methods, effectiveness and challenges faced while improving research and evaluation related to continuous quality improvement by the comprehensive web-based interactive science management systems supporting decision makers of the scientific institution ranging from operational to strategic management and while transforming insights into an innovation impact, using the example of Polish physical education higher schools. The author presents a fully developed system, with a brief outline of crucial advantages and benefits, illustrated through a case study.

CHALLENGES

From a practitioner's point of view (a person involved in process), periodic evaluation of scientific units in Poland, which takes place every 4 years, has revealed common issues: (1) **information asymmetry**, marked by: limited information available to decision makers concerning scientific effectiveness of employees, incomplete information management available to the authorities and committees which govern and advise the scientific units, science policy based on subjective feelings rather than on facts; (2) **lack of unified open sources** which would ensure availability of and accessibility to the common scientific data structure (incl. data enlargement), unique scientists' ID, open-access ISSN, ISBN, ISMN databases, standardised format of data transfer acceptable by all scientific databases; (3) **low quality of data collected** which involves: overflow of (unnecessary and inadequate) data, missing data because the scope of data collected is not defined and as a result of data duplication, incorrect data due to lack of their verification; (4) **chaotic reporting process**, which involves decision makers only at the last stage of the process, fuzzy responsibility for data reporting (multiple sources, multiple users with knowledge and experience at varying level, incl. those who did not graduate in the field of scientific information or library), lack of consistency, verification and control of the data (often as a result of routine, time pressure or wrong management); (5) **vague legislation** that on the one hand allows for an unfettered interpretation, and on the other is limited by uncomprehended intention of the legislator; (6) **volatility of rules** governing the evaluation that does not allow for long-term strategy, forcing changes; (7) **unready data reporting system** that requires waiting for missing functionalities, which is constantly changed and corrected, and marked by intricate and incomprehensible logic for the user.

Academy of Physical Education – institution, such as a university, providing higher education in the field of sports science (physical education, physiotherapy, recreation, sport), having the right to confer all academic titles (from bachelor to a professor with the right to confer a "doctor honoris causa"). In Poland, there are six academies of physical education: the Academy of Physical Education in Katowice, Kraków, Poznań, Warszawa, Wrocław and the Academy of Physical Education and Sport in Gdańsk [3].

Continuous Quality Improvement – a management philosophy that encourages to look for ways to improve the output of scientific work by an ongoing evaluation process that helps scientific institutions to improve performance and take initiatives to increase quality.

Data Science Professional – a person possessing the full range of scientific, analytical and technical skills which allow for an understanding of the mechanism, implications, benefits and challenges faced by a scientific unit, which specialises in analysing data using big data and cloud technologies to ensure complete, timely and accurate reporting to support decision makers.

Polish physical education higher schools – in the article it is the operational term for the Academies of Physical Education and related public or non-public higher schools, that educate at least on one of the units related to sport science (physical education, physiotherapy, recreation, sport) [4].

Science intelligence – it is about making decisions by the scientific institution in the area of scientific activity and productivity, using analytical resources, aimed at continuous improvement of the quality of scientific activities, transforming them into insight, innovation and impact.

Research Intelligence Systems – its goal is to inform about information and decision-making systems supporting universities and providing information about the current scientific activity. This allows for planning the results obtained by research teams and managing all research and development resources and assets in line with the strategy.

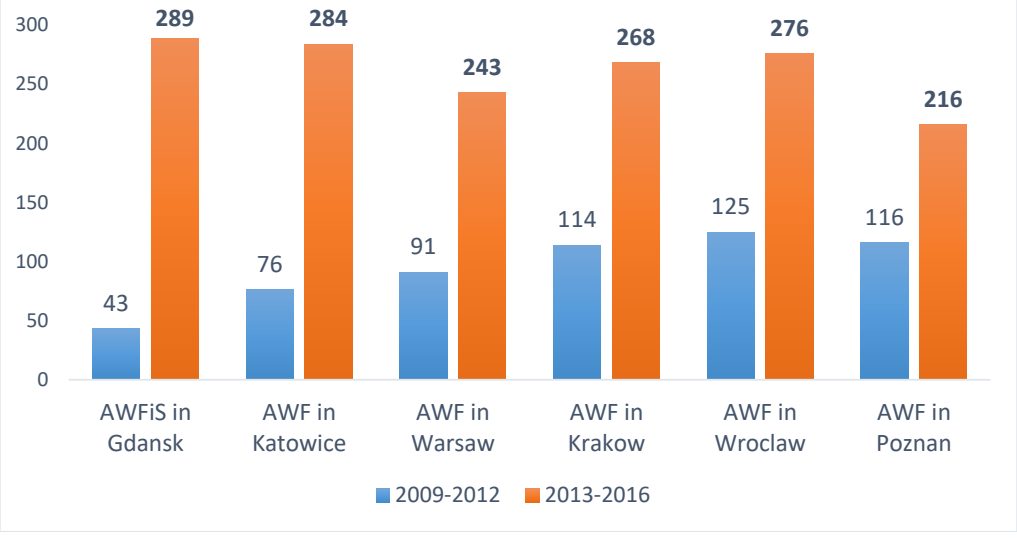
TOWARDS PRODUCTIVITY IMPROVEMENT

The previous institutional evaluation in Poland was held in 2013 and involved 963 scientific units. For the first time, the evaluation was performance-based, funding-oriented and conducted within a public-private partnership. Within 2,5 months, the scientific units – representing: life science, social science & humanistic, applied science & engineering, art science – evidenced 952,768 achievements (i.e. publications, monographs, patents, grants, revenues, conferences, awards, artistic works etc.). After preliminary verification, 807,671 of them were qualified for the further evaluation. Out of this group, 30,763 achievements were rejected by evaluators. The final assessment focused on 424,220 achievements, among which only 9,943 have been verified by 160 national reviewers, grouped into 30 subject teams [3-5].

From the perspective of the scientific institution, the statistics mentioned above do not say much. The key findings involve the following questions: (1) which elements of the unit's achievements did not meet the formal criterion of qualification because: (a) they were not assessed in a given area of science (output which is not specific for a given scientific unit, i.e. artistic works for life science); (b) they were excluded from the final assessment as unreliable, e.g. number of conferences, citations, awards, etc.; (c) they failed to meet the inclusion criteria, e.g. non-scientific character of publications, the volume of monographs smaller lower specified in the regulations, etc.; (2) which of the other limitations have key impact on the assessment due to: (a) unclear concepts or unspecified issues; (b) incorrectly designed proportion of achievements as well as distinguishing achievements which appears in the minimal scope in a given field; (c) given evaluation criterion not appearing in the determined scientific area; (d) disproportionate assessment of institutions representing different areas or disciplines; (3) why activities specific for given field are not taken into account, i.e., coaching degrees in physical education.

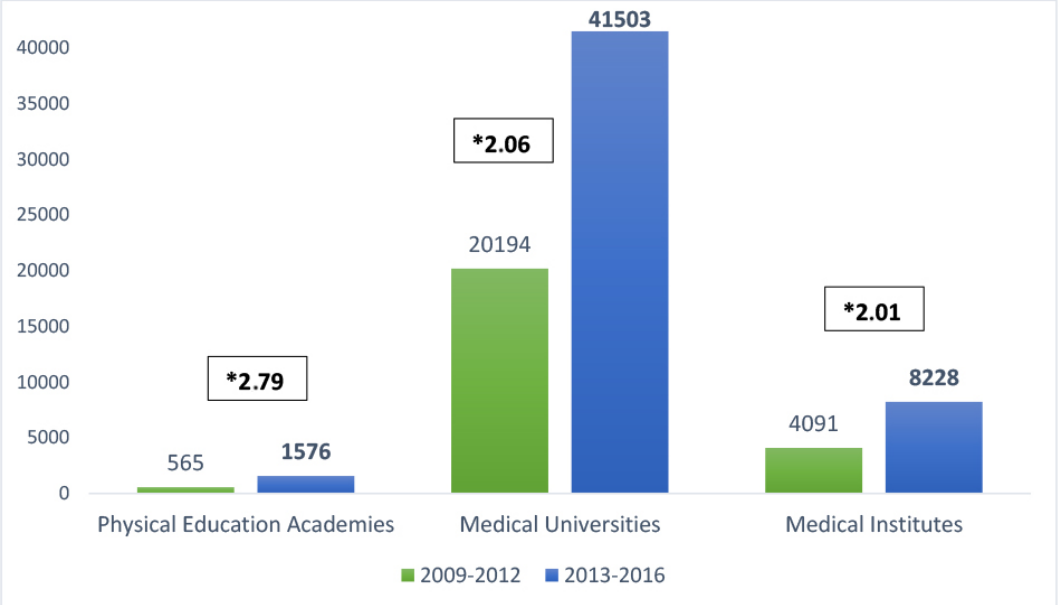
The current institutional evaluation in Poland was commenced at the beginning of 2017, covering 989 scientific institutions and is largely similar to the evaluation carried out in 2013 regarding assessment criteria, regulations and scientific units. However, their results and progress between two evaluation periods will not be discussed further due to editorial restrictions the analysis and comparison of units.

While publishing this article, there were no official results of the institutional evaluation carried out by the Polish Ministry of Science and Higher Education available. Nevertheless, in the case of many institutions, this is just a formality because the last four-year period has been spent on innovative undertakings, stimulating scientists, building research teams, ensuring more efficient use of



Note: AWFIS - Academy of Physical Education and Sport; AWF - Academy of Physical Education.

Figure 1. The dynamics of publications published by the academies of physical education in Poland concerning the highest increase in the number of publications in the journals with the *Impact Factor*.



* dynamic factor

Source: Special report to the Polish Ministry of Science and Higher Education commissioned by the Polish Medical Research Institutes.

Figure 2. The dynamics of publications published by medical institutes and universities in Poland concerning the highest increase in the number of publications in the journals with *Impact Factor*.

resources. This claim is confirmed by the number of publications in journals with an *Impact Factor* published by scientists from academies of physical education in Poland [3-7]. The analysis covered two full evaluation cycles of scientific units. They were carried out in 2009-2012 and 2013-2016 (Figure 1).

The whole group is marked by nearly a threefold increase in the number of publications in the years 2013-2016 when compared to 2009-2012. In this group, the highest dynamics was revealed in the case of *Akademia Wychowania Fizycznego i Sportu im. Jędrzeja* Śniadeckiego *w Gdańsku* (572%) and *Akademia Wychowania Fizycznego im. Jerzego Kukuczki w Katowicach* (274%). The dynamics of *Akademia Wychowania Fizycznego Józefa Piłsudskiego w Warszawie*, *Akademia Wychowania Fizycznego im. Bronisława Czecha w Krakowie*, *Akademia Wychowania Fizycznego we Wrocławiu* amounted to 167%, 135% and 121%, respectively. The lowest dynamics was noted in the case of *Akademia Wychowania Fizycznego im. Eugeniusza Piaseckiego w Poznaniu* (86%).

These results demonstrate the great dynamics in the case of some PE academies, but does the increased number of publications in the journals with the *Impact Factor* always translated into more valuable publications? Perhaps it is linked with higher pressure to publish, improved techniques of article allocation, social expectations, local legislation, struggle for ranking place and consequently the amount of public subsidies [2, 8-13].

A growing trend was not revealed only in the case of the PE Academies (n = 6). The corresponding trend was observed at medical universities (n = 11) and medical institutes (n = 22). Analogical analysis of publications in journals with *Impact Factor* revealed that increased number of publications is a common achievement for 3 groups of units (Figure 2). Among these institutions, which are cooperating and competing, the academies of physical education showed the highest productivity and scientific activity measured by publications in journals of the highest prestige (179%). Medical universities were marked by the dynamics of 106%, which proves close relations between these types of institutions, both regarding research and providing education in the field of sports medicine. The lower dynamics (101%) was observed at medical institutes that do not carry out didactic activities like universities but focus on research and development instead and are orientated to their implementation and application in practice.

Such an impressive result would not be achievable without success oriented policy with a focus on continuous quality improvement of the PE Academies pursuing Excellent Science, determination and involvement of the institution managers, using performance-based data science systems.

A CASE STUDY INVOLVING A RESEARCH INTELLIGENCE SYSTEM IN SPORT SCIENCE

The wise higher education institution understands and recognises the need for continuous quality improvement and development of a conscious strategy. This awareness also has managers (rectors, deans, etc.) of the academies of physical education in Poland. As a result of the previous assessment of scientific institutions conducted in 2013, the PE Academies have implemented the ***Science Wizard***, a tool that supports them in managing own research potential and output aiming at scientific excellence.

Science Wizard is an innovative[1] solution created by Polish inventors from 4 Medicine Rek PLL (visit http://sciencewizard.pl). The system is intended for scientific institutions bound by public reporting obligation which pertains to essential activities and research and is subject to the periodic assessment.

Science Wizard allows for gathering information about scientific achievements of the employees, such as publications, projects, supervised employees, commercialised study results, key accomplishments, etc. and for subjecting them to ongoing assessment which facilitates HR policy and development of work plans based on research and scientific potential and activity. The system is entirely in line with the Horizon 2020 regarding assigning scientific excellence to the universities and research institutions.

Science Wizard is a powerful analytical and prognostic tool enabling multi-criteria analysis between both own and competing units. Due to its unique concept, the system allows for designing and simulating an optimal organisational structure, ensuring at the same time the best use of own resources and efficient use of assets and capital (human, instructional, material and financial).

Science Wizard facilitates modelling and planning of institutions of the future which are the basis for a modern universities and research organisations credibility, smoothing the achievement of strategic objectives and concurrently developing the managerial competence of management and administrative staff.

BENEFITS AND ADVANTAGES DERIVED FROM USING *SCIENCE WIZARD*

Authorities, bodies and committees which govern and advise the HEIs as well as research institutions gain:

- A tool for constant monitoring of staff and unit achievements along with progress in achieving scientific objectives.
- A solution that facilitates and improve management capability of academic productivity.
- Access to statistics and reports in line with local and international requirements at any time and place.
- A tool that facilitates work and primarily saves time while drawing up various and multi-criterial reports for the internal needs of employees and a unit.
- A tool for analysis of employees' input and output, as well as scientific potential and productivity.
- A solution that identifies employees with a little impact on institution success, as well as achievements which are not eligible for assessment due to incomplete data, duplicates or other formal deficiencies.
- A tool that allows for comparing and carrying out multi-criteria analyses between own units or organisational units (e.g. departments, institutes).
- Access to various data layouts, depending on a receiver and the reason of reporting (internal summary, official reports).
- A tool for advanced support in pursuing a scientific policy of an institution with the use of the, Scientific Scoring Sheet' consistent with international standards on the assessment of scientific units which allows planning and pursuing institutions development strategy, human resources policy, promotion procedures or prize awarding.
- A solution that facilitates management of

1. The system meets characteristics of an innovation found to influence and productivity adoption include relative advantage, compatibility, complexity, trialability and observability [5].

scientific information concerning human resources promotion, professionals activity and collaboration with external entities as well as research projects and service provision.
- A repository of scientific and research information of strategic importance due to constant access to ordered, structured information resources and knowledge gathered at a unit.
- A supportive solution which motivates employees of all levels to participate in actions undertaken by an institution actively, and only just within their formal competence.
- A tool for setting a work plan for the entire institution, including roles and responsibilities for individual employees.
- A solution that allows for mapping an organisational structure (departments, institutes, laboratories, etc.) for individual analysis.
- Access to bibliometric data, input indicators, scores, journals, rankings at any time and place.
- A reporting tool is helping to register achievements and scores.
- A transparent system for continuous employee assessment.
- Access to publication and scientometric statistics.
- A solution that allows for establishing cooperation with research teams.
- A tool that supports a development of research groups, motivating and accounting for the practical effects of studies.
- A tool that supports analysis of performance indicators for assessing and benchmarking research capacities.
- A solution that supports dissemination academic and research achievements of employees and a unit by selecting efficient sources of knowledge (regular journals, monographs, conference publications, etc.).
- A tool for gathering up-to-date information from various sources, such as the Research & Development Organisations, National Science Agencies, aggregating them in one place.
- A solution that helps identify key contributors to a unit's success and practical effects of research and development, targeted at implementation and practical application.
- A powerful tool for designing an organisational structure that allows for identification of optimal research teams which will become core staff at the future units, which in turn are the basis for a university to receive credentials.
- A tool building and maintaining a competitive advantage.
- A tool expediting pro-quality transitions thanks to the Business Intelligence model applied, which enables constant analysis, planning and implementation of development strategy.
- A tool supporting restructuring related to science and higher education trends as far as planning, supervision and efficient use of resources are concerned.

PERSPECTIVES AND RECOMMENDATIONS

This year's assessment (2017) of scientific institutions follows the evaluation which was held in 2013 and strives to establish the nature of institutional evaluations, which would be more alike to 'evaluation engineering' and practically show who has maintained the status quo, and who has succeeded in being more effective and flexible in presenting own achievements.

That is why the next institutional evaluation in Poland should evolve towards combining both the historical assessment and the emphasis on plans with extensive use of peer review panels, including the best practices of more advanced research countries [14-21].

The Norwegian model is commendable because the overall evaluation process includes: administrative organisation, dialogue with research institutions or their institutional representatives, appointing committees/panels, commissioning analyses (bibliometric and scientometric), fact sheets, self-assessments, hearings, evaluation reports (including quality control), summary reports, public presentations [22-26].

Also Portuguese model is commendable due to the involvement of a large number of experts from 46 countries [27-30], involvement the European Science Foundation [31], face to face meetings the panel members with a good deal of work also done remotely, two stage assessment process concluded with the grade and financial outcome. Beyond mentioned above, the worth of recommending is the United Kingdom model [32-35], which belongs to the most qualitative and top ranked in the world for excellence (called the *Research Excellence Framework*). The UK model is based on the expert review. The universities choose the Units of Assessment (out of 36 available across all research disciplines) to submit an evidence of the impact of their research. Submissions contain up to four research outputs per scientist, impact case studies and details of

the strategy for achieving impact, information and data about the research strategy, students, staffing, income, facilities and collaborations. Experts assess the quality of research outputs, the impact of research beyond academia and the research environment which result is the overall quality.

The Polish Ministry of Science and Higher Education currently is working on a new law on higher education 2.0 along with the whole scientific and academic community, whose representatives (3 working teams) [36-40] have prepared their proposals for system solutions to modernise academia. The key concepts concern the new quality of higher education, new requirements for academics, modern management, new financing model of universities and scientific institutions, as well as building a new competitive high level of education and research, what in consequence will need functional categorisation of the scientific institutions and creating the new institutional evaluation.

Assessment in 2021 ought to be entrusted to a new entity '*The Polish Centre of Scientific Excellence*' based (among others) on the Committee for Evaluation of Scientific Units, which should be designated in a separate legal act, have a specialised office serving scientific units, regional administration and government, with a permanent staff of specialists, cooperating on a permanent basis with evaluators from the best foreign institutions on developing assessment models that incorporate and maximise the usefulness of qualitative and quantitative assessment methods [14, 41], having a real impact on a number of public subsidies granted to the scientific units [42, 43]. This will allow for achieving the strategic goals of Polish science, building competitiveness and establishing stronger relations with the economy [44-47].

CONCLUSIONS

The comparison of an institutional evaluation of scientific units conducted in 2013 and 2017 with focus on PE Academies provided solid evidence that academies systematically increase productivity and effectiveness. These results are also confirming by places in the prestigious Shanghai Ranking's Global Ranking of Sports Science Schools and Departments [48].

They would not succeed without building competitive advantage with the Research Intelligence Systems. The presented case showed that the *Science Wizard* supports scientific institutions in overcoming the challenges, the enhancement of productivity, innovation and competitiveness strengthen institution´s strategies. *Science Wizard* and its experts allow managers to select the best resources according to the institution´s priorities, make the correct decisions at the right time and get new initiatives on the road towards the Excellent Science.

While observing dynamic changes in science, economy and social expectations, it is most crucial to support the R&D strategy by the Research Intelligence Systems, which should lead to the development of scientific potential for the innovative economy and advanced research. The human factor plays a key role due to the accumulated knowledge, experience, competencies. Management of these resources, thus stimulating creativity, cooperation and interaction with other participants of the implementation process, will be the main aim of scientific institutions focusing on increasing and facilitating internationalisation [49, 50] of Polish research, innovation and higher education.

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