On the Role and Assessment of Research at European Universities of Applied Sciences

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The relevance of the Universities of Applied Sciences (UASs) is growing in a world where practice-based learning and research are essential to meet societal development goals. Public policies for science, technology, and innovation must, therefore, account for an increasingly complex context where higher education institutions of varied shapes co-evolve. On the other hand, the increasing influence of international ranking systems and of bibliometric indicators calls for a critical revision of their adequacy to account for UASs' key characteristics such as the importance of interdisciplinary and transdisciplinary approaches when tackling context-based challenges. This paper examines the roles of UASs in contemporary knowledge-intensive societies and critically addresses dominant research evaluation approaches. It is argued that i) qualitative approaches based on the visualization of bibliometric data can provide useful perspectives on interdisciplinarity, ii) the assessment of stakeholder engagement should be incorporated in rankings such as U-Multirank, and iii) knowledge dissemination at large could be assessed using Altmetrics indicators.

Keywords: universities of applied sciences, research assessment, professional doctorates, higher education rankings, bibliometrics, Altmetrics

INTRODUCTION

Higher education institutions (HEIs) act as "transformative institutions," contributing to socio-economic regional development, the creation of social capital, and as educators for democratic and responsible citizenship (Gaisch et al., 2019). The creation of new knowledge through research is central to the fulfilment of these objectives (Meyer-Krahmer & Schmoch, 1998; Perkmann & Walsh, 2007). HEIs' research and development (R&D) activities also foster teaching excellence, which is essential for superior higher education and training. The transfer of knowledge to society occurs via different mechanisms, e.g., training of graduates, creation of enterprises, production of technical and scientific publications, and institutional cooperation. Thus, HEIs promote innovation activities through the combination of teaching, research, and knowledge valorization, and by playing an effective role in innovation ecosystems (Bramwell & Wolfe, 2008; Charles, 2006).

Practice-oriented HEIs, i.e., universities of applied sciences (UASs), were adopted in the 1960s and 1970s to reduce pressure on university admissions and also to enroll students who demanded higher education but did not intend to pursue a scientific career. The development of research in UASs, either by a policy drift or a practice drift, led to complex dynamics of differentiation and convergence with "classical" universities. Currently, most UASs develop research even though this is greatly influenced by differences among different topic areas (Lepori, 2008). Some national authorities have taken explicit measures toward the academization and expansion of UASs either by imposing collaboration with universities, e.g., in Belgium, or by governance models that permit and support research, e.g., in Finland or Norway (Taylor et al., 2008). In other countries, such as Portugal, Norway, Switzerland, and Austria, a clear divide among universities and UASs still exists alongside with the fulfilment of their research mission. The research drive at UASs can also be attributed to non-policy factors such as: 1) the increased qualifications of teaching staff, predominantly holding doctorates; 2) the need to contribute to the technological sophistication of local and regional enterprise ecosystems; 3) the increasing relevance of international HEI rankings (that do not take into consideration UASs' scope specificities but value traditional research outputs such as publication volumes); 4) increased international student mobility that promotes new cooperation contexts; and 5) the opportunity to attract external funding through competitive calls for research and innovation projects. The effective participation of students in real-life research projects also clearly supports their employability. This can only be achieved if the teaching staff is involved in practice-oriented research, especially at the doctorate level. All these factors create a complex setting for the role of research at UASs.

The practice-based nature of research at UASs calls for assessment protocols that differ from those applicable to "classical" universities. One such difference is the stronger focus on the role of the societal impact of research. However, its evaluation has proven difficult (Coombs & Meijer, 2021). Generally, current evaluation frameworks for societal impact include the use of case studies, a narrative component, and a logic model (for visualization of input activities, outputs, and outcomes) (Raftery et al., 2016), and often supported by bibliometric indicators. Coombs and Meijer (2021) have recently presented a thorough review and concluded that there is a need to create a new framework where the context and process of practice-based research, and UASs' stakeholders are included. Nevertheless, "traditional" evaluation tools such as bibliometric indicators are still a needed component of any research evaluation exercise, including at UASs. They are considered, for example, by major HEI rankings currently in use. At the same time, several key international initiatives advocating responsible research evaluation and use of indicators have been gaining momentum.

In face of the above, the objectives of this paper are to review the roles of research in UASs and to critically address the use of rankings and bibliometric indicators in the context of research evaluation frameworks. Also, new approaches for the evaluation of interdisciplinarity and transdisciplinarity (key traits of research at UASs) are proposed and illustrated.

In the following section, the status of UASs in European countries is revised, namely, focusing on their practice-based nature and their importance to the fulfilment of UASs' second mission. This is followed by an analysis of the international context of institutional research evaluation, namely, by addressing key ranking systems, common and emergent bibliometric indicators, and important international initiatives on research assessment. Next, new qualitative and quantitative tools for research assessment are presented and illustrated. The paper ends with major conclusions and directions for future work.

THE ROLES OF RESEARCH AT UNIVERSITIES OF APPLIED SCIENCES IN EUROPE

To Divide or Not to Divide, That Is the Question

UASs in Europe have evolved heterogeneously over the last two decades and throughout its geography. Clear higher education (HE) division systems, not so clear division systems, and no division at all systems exist as illustrated next.

In Norway, several UASs deliver doctorate programs and the integration of UASs and universities is still active (Elken & Frølich, 2017). The Norwegian UAS sector illustrates possibly the clearest expression of a policy drift. The converging of the UAS and university sectors is not only tolerated, but keenly backed by the government.

In Austria, UASs, founded specifically to provide academic vocational training, are being converted into "full" universities in that they encompass a broad range of scientific areas and fulfil HE's four missions (Schüll, 2019). Disciplines typical for UASs, e.g., engineering or business administration, have been expanded to include, for example, public administration, health care, or social work. From a formal standpoint, the degrees earned at UASs are identical to those earned at universities. The increase in student numbers, study courses, and research activities in the UAS sector originated a blurring of the originally separate profiles of the UAS and university sectors (Schüll, 2019).

The German, Swiss, and Finnish cases illustrate that a proactive approach toward the regulation of research may allow research and development (R&D) activities to be conducted without questioning the binary divide.

In Germany, universities emphasize basic research while UASs concentrate on application-oriented R&D. Additionally, UASs are usually smaller and frequently seen as more locally oriented when it comes to cooperation with small and medium-sized enterprises. Conversely, universities tend to focus on R&D collaboration with "bigger and technologically more bold companies" (Kroll et al., 2012).

In the case of Switzerland, HEIs strive to boost their status and working conditions by performing R&D and, therefore, have grown to be more akin to universities. This is an example of "academic drift." The applied research directive has been established to distinguish UASs from universities. This endeavor has been largely fruitful in technology-led areas while it has been a cause of tensions in other disciplines. The development of R&D has occurred essentially in technologic areas (e.g., chemistry and construction) and accounted for 70% of UASs' R&D activity in 2004 (Lepori, 2008).

In Finland, assimilation of the research and teaching areas is a key target for UASs (Kajaste, 2018; Taylor et al., 2008). Due to the legal framework and the history of the UAS sector, the focus for educational and R&D activities is essentially regional; their activities are centered on the needs of the society at large, funders, and customers. This makes UAS R&D different from the basic research carried out at universities.

In Portugal, a binary division in higher education was determined by the government in the late 1980s and further strengthened during the implementation of the Bologna three-cycle system (Veiga & Amaral, 2009). UASs (*Institutos Politécnicos*) have a clear practice-based teaching mandate and research volume and quality have been steadily increasing over the last years. UASs, such as the Polytechnic Institute of Bragança, have been consecutively well positioned in international rankings (e.g., in U-Multirank (promoted by the European Commission) and in SIR (developed by the SCImago group), even ahead of some Portuguese "classical" universities. They have access to competitive funding for both basic research (through the Portuguese National Foundation for Science and Technology) and for applied research (through the Portuguese National Innovation Agency) as do universities. Thus, from a research practice and performance point of view, the HE divide is not that clear except for the fact that Portuguese UASs cannot deliver doctoral programs.

It should be mentioned that outside Europe the same trends can be observed. For example, in Malaysia, UASs lecturers are now required to do research, publish, and perform other scholarly activities as part of their job duties. Performance in research activities has been set as one of the new criteria evaluated for promotion, in contrast with previous systems based only on seniority (Sanmugam & Rajanthran, 2014).

The increasingly important and diversified roles that research plays in the UAS sector calls for adequate assessment frameworks. However, research evaluation at UASs is far from a linear process as it is influenced by intrinsic (e.g., its practice-based nature) and contextual factors (e.g., existing HEI ranking systems), which will be discussed next.

RESEARCH EVALUATION AT HEIS

International HEI Rankings

The first university ranking was published in 1910 in the United States by James McKeen Cattell (1860–1944). His computation of the "scientific strength of institutions" enumerated U.S. universities in descending order depending on the total number of eminent scientists hired (Hammarfelt et al., 2017). More than a century later, HEI rankings have come to be gradually more important tools for evaluating the "quality" of HEIs' activities. Interest in HEI performance has soared since the first global ranking, the Academic Ranking of World Universities (ARWU), was published in 2003 by the Institute of Higher Education of the Shanghai Jiao Tong University. Examples of some existing rankings include the SCImago Institutions Ranking (SIR), the U-Multirank, the CWTS Leiden Ranking, the Times Higher Education

World University Rankings, and the World's Universities with Real Impact ranking (WURI). The advent of rankings can be understood in part as a response to pull-driven demands and developments in HE, namely, internationalization, globalization, and economization (Hammarfelt et al., 2017). Additionally, global HEI rankings are often used as a portrait of a nation's global competitiveness and contribute to the importance of HE to the economic and societal growth of nations (Marginson & van der Wende, 2007). Today, politicians often use HEI rankings as an indication of economic power and aspiration, students use them to help select institutions, and universities use them to assist with setting and specifying objectives or for branding and publicizing purposes. Despite methodological shortcomings, world rankings go beyond benchmarking performance and have turned out to be good examples of HE marketization (Hazelkorn, 2009).

Struggling between not intending to put public emphasis on ranking positions and privately making efforts to avoid falling, HEI leaders take it for granted that rankings are here to stay and take them into due consideration as does every other HEI (Griffith & Rask, 2007). Hence, global rankings seriously influence their strategic planning processes. In fact, regardless of being quite recent, solid evidence already exists that rankings influence academic behavior and decision making. This includes curriculum development, teaching vs. research balance, undergraduate vs. postgraduate balance, and prioritizing domains that probably lead to better ranking positions. Evidence exists on favoring domains particularly productive in publishing or securing funding (Hazelkorn, 2009). Areas with a more modest publication profile, such as humanities, social sciences, business, and education, are particularly affected. The influence of university rankings, the current "publish or perish" dilemma (McGrail et al., 2006), and the influence of journal quality (Straub & Anderson, 2010) have pushed academics to boost productivity and enlarge collaboration networks and markedly altered scientific publishing patterns. The volume of co-authored articles has risen along with the collaboration volume (Börner et al., 2005).

In fact, most HEI rankings rely on bibliometric data as illustrated by the SIR ranking, developed by the SCImago research group (Spain) and by the U-Multirank (developed by a consortium) and supported by the European Commission. To establish the SIR for a particular year, the results obtained in the previous five years and ending two years before that year are used. The following metrics, size-normalized or field-normalized in some cases, are used to determine the global research rank for each HEI: number of documents indexed in Scopus; article citation values; scientific output included in the top 10% of the most cited; number of documents in which the institution is the main contributor; output produced in collaboration with international institutions; number of publications in first quartile journals; percentage of documents published in open access journals or indexed in the Unpaywall database; and the number of different authors from an institution in the total publication output of that institution. In the case of U-Multirank, which relies partially on information provided by the HEIs themselves, the following metrics, normalized in some cases, are used: citation rate; number of publications indexed in the Web of Science Core Collection database; external research income; art-related output; percentage of top cited publications; interdisciplinary publications; post-doc positions; professional publications; and open access publications.

As exemplified, international rankings do not consistently differentiate between "classical" universities and UASs. In fact, they apply the same evaluation and ranking criteria to every HEI, not considering the existence of different profiles and aims. Nonetheless, it is notable that U-Multirank takes into account professional publications.

The fact that most international HEI rankings use bibliometric data calls for a critical overview of commonly used key metrics and emergent indicators.

Bibliometric Indicators

Bibliometrics can be defined as the study of groups of interconnected documents, for example, scientific literature (Palmblad & van Eck, 2018; Waaijer & Palmblad, 2015), and corresponding citation frequency and patterns (Scruggs et al., 2019; Xie et al., 2020). Bibliometrics help in the evaluation of research activities to reflect comprehensive data related to a particular researcher, scientific field, institution, or country. Because of the partial and one-dimensional nature of typical indicators, a set of metrics is often used. Also, research performance may be affected by a wide range of factors, including personal aspects (e.g., age), career positioning (e.g., rank), organizational duties (e.g., teaching, mobility), financial issues (e.g., research funds), or field-specific publishing practices (e.g., format, periodicity, collaboration patterns). For example, while books are important outputs in the humanities, they are replaced by journal articles in most other scientific areas. This creates a wide range of possibilities for the evaluation of scientific performance. Also, it is tricky to rank individual contributions to multi-authored papers (Triggle et al., 2021), especially when the number of authors is in the double or even triple digits as happens often in the physics area. Consequently, it is challenging to extract significant information from such a wide range of variables (Díaz-Faes et al., 2015). Nevertheless, bibliometrics may open up a meaningful perspective on the activities and impacts of research (Fernandes et al., 2020; Scruggs et al., 2019; Xie et al., 2020) if the advantages, disadvantages, and specificities of the used metrics are acknowledged.

Research productivity is typically determined by the volume of papers published in peer-reviewed journals. On the other hand, research impact is usually assessed by the level of citations. The connection between scientific publications volume and impact, and international rankings of HEIs has been addressed by several scholars (Law & van der Veen, 2008; McKercher, Law, & Lam, 2006; Xiao & Smith, 2006). However, it has been increasingly claimed that a qualitative approach for assessing research quality would be more adequate than a purely quantitative one as it is strongly associated with particular characteristics of scientific journals within their subject area (Lee & Law, 2011; Pechlaner et al., 2004). Also, inherent productivity differences exist among scientific areas. In the science, technology, and medical domains, scientific knowledge becomes obsolete within three to four years, whereas in the social sciences and humanities domains this may well take up to ten years or more. Also, the teams involved in the science, technology and medical domains are much larger than those in the social sciences and humanities domains, where researchers often conduct research solely, and publish so or in small teams. This results in a higher number of co-authors per publication in, e.g., physics and astronomy. Citation analysis has been used for decades to determine the impact of articles (Garfield, 2006; Scruggs et al., 2019); however, several drawbacks of this approach should be mentioned. For example, citations are only a proxy of research excellence, expressing just one type of intellectual connection between authors (Karaulova et al., 2020). Another disadvantage of the citations metric is that it is too sensitive to single highly cited publications. Researchers, institutions, or countries with relevant publications in highly cited areas will have a relative advantage (Aksnes et al., 2012; Katz & Hicks, 1997; Wang, 2018).

The use of size-normalized citation impact metrics, such as citations per publication or field-weighted citation impact metrics, is advisable when comparing the research impact of entities of different sizes or profiles. H-indices as well as its myriad of normalized and standardized versions (Bandt & Dacey, 2017), that measure both the productivity and citation impact should be used with care when comparing entities of significantly different discipline profiles and sizes (Waltman & van Eck, 2012; Triggle et al., 2021). The field-weighted citation index developed by Elsevier corresponds to the ratio of document citations to the average citations number of all comparable documents in a three-year period. Each scientific area makes an identical contribution to the metric, which reduces differences in citation patterns. It is normalized against the year of publication, the document type, and corresponding scientific areas. Many other metrics could be mentioned, such as the ratio of the number of published articles to the total number of researchers as an indicator of research quality (Gu & Blackmore, 2017; Lee & Law, 2011), and journal-specific metrics. Journal metrics include the SCImago Journal Ranking (SJR) and the Journal Impact factor (JIF, Clarivate). The SJR is a measure of the scientific influence of scholarly journals that accounts for both the number of citations received by a journal and its "reputation." The JIF reflects the yearly average number of citations of articles published in the last two years in a journal as indexed by Clarivate's Web of Science. It was initially conceived as a tool to help librarians identify journals to purchase and not for the assessment of the quality of a research article.

From the above information, it is observed that new approaches to assessment are required to provide a realistic and comprehensive measure of the value of research. This has been addressed by the international scientific community and has originated a series of initiatives aimed at framing fairer and unbiased research evaluation processes.

International Initiatives on Research Assessment

Several key international initiatives related to research assessment have been organized in the last years and increasingly adopted by HEIs and governmental organizations in charge of assessing research performed by these institutions.

The Declaration on Research Assessment (DORA)[1] acknowledges the need to improve the processes by which scientists and research outputs are evaluated. The founding group developed a set of recommendations that focuses primarily on practices related to research articles published in peer-reviewed journals. In short, it is recommended to 1) eliminate the use of journal-based metrics, such as Journal Impact Factors, in funding, appointment, and promotion considerations; 2) assess research on its own virtues instead of on the basis of the journal in which results are published; and 3) exploit the opportunities offered by online publication (e.g., easing needless limits on the number of words, references and figures in articles, and using new indicators of quality and impact).

The Leiden Manifest for Research Metrics proposed 10 principles for the measurement of research performance (Diana Hicks & Wouters, 2015): 1) quantitative evaluation should support qualitative, expert assessment; 2) measure performance in the context of the research missions of the institution, department, or researcher; 3) defend excellence in research that is locally relevant; 4) maintain transparent, open, and simple data retrieval and analytical methods; 5) allow for the external verification of data and analysis; 6) take into consideration differences in publication and citation practices among scientific areas; 7) base evaluation of individual researchers on a qualitative verdict of their output collection; 8) avoid misplaced concreteness and false precision; 9) recognize the systemic effects of assessment and indicators; and 10) scrutinize indicators regularly and update them.

The Metric Tide report addresses the use of metrics in research assessment and suggests the concept of their responsible use be based on the following principles (Wilsdon et al., 2015): 1) robustness: grounding indicators on adequate information in what concerns accuracy and context; 2) humility: recognizing that qualitative evaluation and expert assessment must be supported by metrics; 3) transparency: safeguarding that data collection and analyses are clear and open, and that the evaluation results can be scrutinized by those being evaluated; 4) diversity: variances among scientific areas must be taken into consideration and, thus, a multiplicity of indicators should be used; and 5) reflexivity: recognizing potential systemic effects of indicators and reviewing them in accordance.

The Hong Kong Principles for researchers' evaluation presented five key tenets (Moher et al., 2020): 1) responsible research habits; 2) translucent reporting; 3) open science (open research); 4) appreciation of a variety of research categories; and 5) acknowledgement of all contributions to research outputs.

The adoption of these example initiatives and assessment principles is fully voluntary. It is, however, noteworthy that approximately 20,000 individuals and organizations in approximately150 countries had signed DORA by mid-2021[2]. This shows that responsible research assessment is gaining momentum worldwide.

RESEARCH EVALUATION AT UNIVERSITIES OF APPLIED SCIENCES

Raftery et al. (2016) compiled more than 20 models and frameworks for research evaluation. Among these, six approaches were systematically present: the Payback Framework, the Research Impact Framework, the Canadian Academy of Health Science Framework, the Monetization Framework, the UK Research Excellence Framework, and the Societal Impact Assessment Framework.

In a recent study, Coombs and Meijer (2021) critically reviewed the requirements of a research evaluation framework adapted to UASs. The authors concluded that the requirements for evaluating the societal impact of research done by UASs call for the use of the case study as a tool for formative research evaluation as well as real-time evaluation, where stakeholders are included to create a bottom-up approach for research. They report that in The Netherlands, the BKO national evaluation framework includes asking UASs to choose indicators that echo the following aspects of practice-based research: a) research contribution to knowledge development; b) research contribution to practical knowledge for the professional field, to society at large, and to innovation; and c) research contribution to practical knowledge, up-to-date education, and professionalization of lecturers.

A common trait of the abovementioned frameworks is that in general, bibliometric data are seen more in a supportive role of qualitative assessments than as prime indicators of research quality and impact. This is clearly in line with the international initiatives on research assessment previously described. In fact, the research outputs and outcomes of practice-based institutions such as UASs go well beyond academic papers and must consider other contributions to positive changes in their economic, social, and/or environmental context. The practices and patterns of social interaction and the contextual nature of transdisciplinary research (typical of UASs) result in different performance expectations than traditional, curiosity-driven research (Steelman et al., 2021). Societally relevant knowledge is not necessarily associated with scientific relevance or high publication output (Bornmann, 2012; Holbrook & Frodeman, 2011; Nightingale & Scott, 2007). While more conventional disciplinary research has evolved relatively clear expectations for what constitutes quality (e.g., publication productivity, peer review processes, journal impact factors, citations), corresponding criteria, metrics, and evaluation processes are less consensual for context- and practice-based research (Belcher et al., 2016). In particular, the use of "traditional" bibliometric indicators (e.g., based on volume of publications and/or respective citations) is essentially not adequate. For example, the percentage of interdisciplinary publications in an HEI output is used to compute the U-Multirank, but as a percentage of an institution's research publications within the area's top 10% publications with the greatest "interdisciplinarity scores." Therefore, it focuses on an "elite" group of publications and does not allow for a coherent assessment that considers specificities related to the scientific profile of a particular UAS and/or R&D challenge.

Inter- and Transdisciplinarity

According to the Organization for Economic Cooperation and Development (OECD, 2016), significant features of technology development require cross-disciplinary institutional spaces. Moreover, the League of European Research Universities recognized recently that many of the most pressing societal and scientific challenges as well as exciting avenues for research and innovation are situated at the intersection of academic disciplines (Wernli & Darbellay, 2016). Thus, contemporary, context-, and practice-based research demand an interdisciplinary and transdisciplinary approach. The former extends beyond mere interdisciplinarity by its focus on dealing with real-world questions (Bailly & Gibson, 2017) and on integrating the full range of relevant stakeholders in the research process, namely, by including the so-called "affected" actors who are locally bound to the problem to be solved (Guimarães et al., 2019; Renn, 2021; Schikowitz, 2020). In fact, the combination of inter- and transdisciplinary scientific methodological competences as well as professional experience or background of UAS professors has been proven to be key in approaching complex societal challenges such as sustainable development (Ringel et al., 2018). Therefore, inter- and especially transdisciplinarity are key aspects to consider when assessing the quality and impact of research at UASs.

The wide availability of bibliometric data opens new avenues for extracting qualitative information that can be used to support research assessments of UASs and HEIs in general. In particular, one can suggest that the assessment of scientific topics coverage and interdisciplinarity traits using qualitative appraisals of bibliometric data could provide information on the quality and impact of research activities at UASs complementary to that provided by quantitative approaches.

Bibliometric data obtained from databases such as Scopus (Elsevier) or Web of Science (Clarivate) can be assessed by advanced tools such as those provided by the freely available VOSviewer software. Besides constructing and displaying bibliometric maps, it allows the identification of clusters, networks, and automatic term identification, e.g., in titles and abstracts (Rizzi et al., 2014; Xie et al., 2020). This facilitates a combined mapping and clustering approach (Waltman et al., 2010). Colors are used to indicate clusters (entities with strong links). The size of a circle shows the number of publications of the corresponding entity (e.g., topic, country). The distance between two circles approximately indicates the strength of the link (e.g., co-authorship) between the corresponding entities (Perianes-Rodriguez et al., 2016).

Term mapping of titles and abstracts of scholarly output can provide information on research topics, their co-existence, and inter-relation at a particular institution (or country, research group, etc). Terms are identified by examining the titles and abstracts using natural language processing techniques. The most important terms are chosen by a selection algorithm implemented in VOSviewer (Rizzi et al., 2014). General terms (e.g., "conclusion," "method," and "result") are not mapped. This is exemplified in Figures 1 and 2 for the Polytechnic Institute of Bragança (IPB, Portugal) for the 1995–2020 period based on Scopus data obtained as at July 2021.

FIGURE 1
MAPPING OF RESEARCH TOPICS AT IPB FOR THE 1995–2020 PERIOD

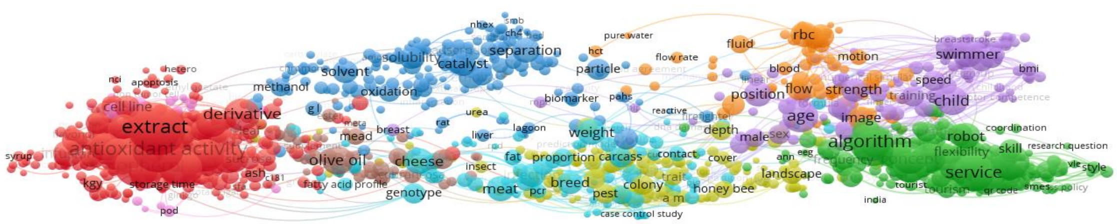

Figure 1 shows that in the 1995–2020 period, most of IPB's scientific publications can be grouped in seven major topic clusters, generally related to 1) information and communication technologies (ICT), 2) sports science, 3) biomedical engineering, 4) animal science, 5) agricultural sciences, 6) chemistry/chemical engineering, and 7) biological and life sciences. It can be observed, for example, that: a) ICT (green) and biological and life sciences (red) are the most productive areas; b) the sports sciences cluster (purple) is closely related to the ICT cluster and to the biomedical engineering cluster (orange); and c) the animal science cluster (light blue and yellow) and the agricultural sciences cluster (brown) are quite interconnected with each other and connected with the remaining clusters.

In Figure 2, a close-up of the sports science cluster for the same period is presented where the interdisciplinarity of this area with the ICT and the biomedical engineering clusters is evidenced.

FIGURE 2
EXAMPLE OF INTERDISCIPLINARITY OF RESEARCH TOPICS AT IPB FOR THE 1995–2020 PERIOD

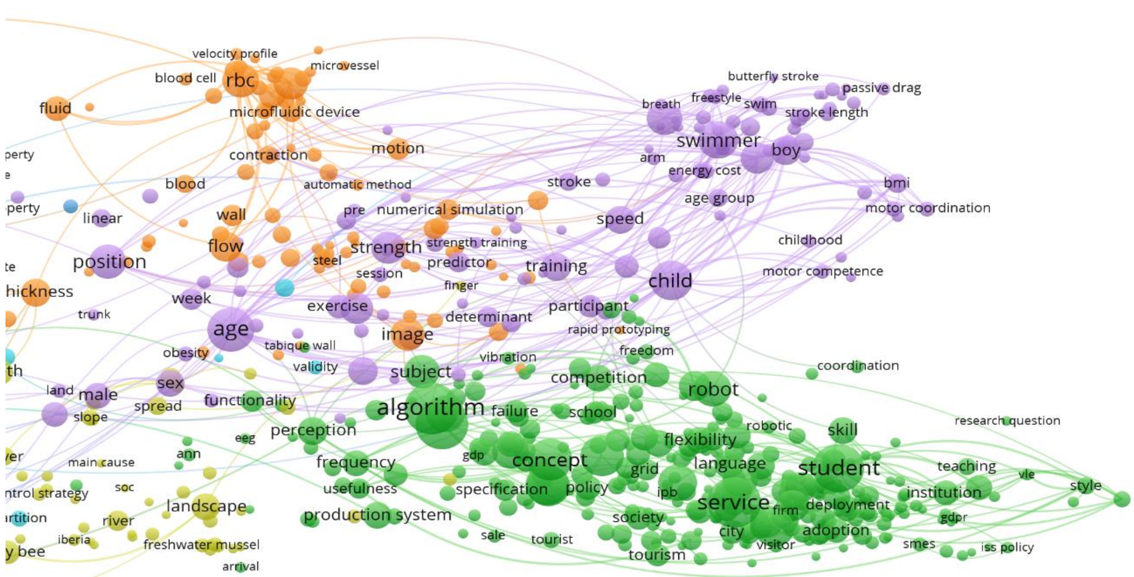

Figure 2 indicates that relevant clusters exist other than those that show up (ICT and biological and life sciences) if only productivity (number of publications) or citation metrics are employed as these reflect essentially the existence of "elite" groups or areas (identified as the "bolder" clusters in Figure 1).

The visualization of bibliometric data exemplified above for IPB illustrates the usefulness of this approach in evaluating research at UASs. The visualization of bibliometric data provides relational information that typical bibliometric indicators do not, allowing for a more complete perspective of the institutional research landscape. In general, one could argue that both bibliometric indicators and data visualizations would contribute to a more contextualized and comprehensive picture of the academic activity of research organizations. For example, in the above example, the interdisciplinarity of IPB's research activity is evidenced. Thus, the use of these tools facilitates the analysis of HEIs of different configurations and sizes, which is particularly relevant when evaluating research carried out at UASs.

The challenges in evaluating transdisciplinary research have been recently addressed in detail by Belcher (2016) and Steelman et al. (2021). Belcher (2016) proposed a quality assessment framework based on four principles: a) relevance, including applicability and social significance; b) credibility, including criteria of reflexivity and integration, in addition to traditional criteria of scientific excellence; c) legitimacy, including criteria of integration and reasonable representation of stakeholder interests; and d) effectiveness, with criteria that evaluate actual or potential contributions to social change and problem-solving. Steelman et al. (2021) provided quantitative and qualitative indicators for assessing transdisciplinary practices and patterns through social network analysis. The defined metrics provide insight into (1) the diversity of participants; (2) whether and how integration and collaboration are occurring, (3) the relative degrees of network stability and fragility, and (4) how the network is structured to achieve its goals.

These evaluation approaches show that in order to deal with real-world questions and integrating the full range of relevant stakeholders, the evaluation of transdisciplinary research processes must focus on participative processes and knowledge dissemination (Belcher et al., 2016; Wolf et al., 2013).

The extent of engagement of stakeholders in the research process will certainly vary from information sharing to active collaboration (Brandt et al., 2013) and, thus, the involvement of stakeholders adds complexity to the conceptualization of research quality. Nevertheless, HEI rankings that rely (at least partially) on data provided by HEIs, such as U-Multirank, could consider aspects such as the size and diversity of networks of the "interested" actors who are influenced or that influence the research questions to be tackled.

Knowledge dissemination can take many forms, e.g., through web pages, blogs, videos, social networks, and more conventional media such as newspapers, reports, and magazines. Naturally, this means a lower availability of easily usable data for computing metrics. Nevertheless, indicators such as those provided by Altmetric could be used to this end as it tracks and captures information from a wide variety of sources: public policy documents, discussions on research blogs, mainstream media coverage, bookmarks on reference managers such as Mendeley, mentions on social networks such as Twitter, and article page-views and downloads. This allows for reporting on the attention that a piece of work is getting from the society at large. As with all metrics, these indicators need to be critically analyzed as they are susceptible to tampering. Nevertheless, Altmetric indicators can signal which research is changing a field of study or having any other number of tangible effects on society at large. Thus, its use could be particularly useful to evaluate practice-based research, namely, at UASs.

CONCLUSION

Successful economies generate and utilize new knowledge as a competitive asset by investing in intellectual progress (Brinkley, 2008). Thus, tertiary education and scientific research have come to be the target of strong political and policy interest as promoters of societal progress in its widest sense. Its prestige and quality are considered as key gauges in a globalized world where the struggle to stand out is increasingly intense.

UASs in Europe differ from "classical" universities in that they provide context- and practice-based learning and research. Their role is closely associated with local or regional development and, thus, their activity tends to be directed to the needs of relevant stakeholders such as regional industrial ecosystems. Accordingly, to fully deliver their mission, UASs around Europe have been developing research strategies that blend learning, professional development, knowledge production, and industry input. This follows a "science-in-a-context model" that extends the boundaries of conventional science to encompass interaction with industry, government, interested community groups, and the general public.

The existence of overly strong incentives and pressure to produce more science, such as international rankings, and to apply for and obtain ever more resources in international competition, has led to the widespread use of bibliometric indicators. Most metrics are ultimately based on the number of publications and corresponding citations. However, according to Campbell's Law, "the more any quantitative social indicator is used for social decision-making, the more subject it will be to corruption pressures and the more apt it will be to distort and corrupt the social processes it is intended to monitor" (Triggle et al., 2021). To try to cope with this, internationally led initiatives have been organized that call for more responsible research evaluation. In the case of UASs, several formal research assessment frameworks exist that call for more qualitative approaches, although their use is still not consolidated.

Interdisciplinarity and transdisciplinarity should be particularly considered when developing research evaluation frameworks for UASs. Extensive use should be made of analytical techniques that can extract relevant information from bibliometric data (i.e., scientific publications) and from non-scientific sources (technical reports, social media, etc.). Scientific interdisciplinarity can be qualitatively evaluated through the visualization of bibliometric data. The assessment of transdisciplinarity should consider two principal dimensions: the engagement of stakeholders and knowledge dissemination to the society at large. The involvement of stakeholders could be incorporated in ranking systems such as U-Multirank by inquiring about the dimension and diversity of UAS stakeholder networks. Knowledge dissemination, well beyond scientific information, could be assessed using Altmetric indicators.

Relevant future avenues of research on this topic include the application of the aforementioned recommendations to a varied set of case studies in order to validate the practicality and usefulness of the proposed approach to research evaluation at UASs, particularly what concerns the highlighted transdisciplinarity attributes.

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ENDNOTE

1. https://sfdora.org/, last accessed July 2021

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