Quality Of Education System As A Determinant Of Socio-Economic Development: Assessment Of Technological Level Of Readyness

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Artem Artyukhov, ORCID ID: https://orcid.org/0000-0003-1112-6891

PhD, Associated Professor, Sumy State University, Ukraine

Iurii Volk, ORCID ID: https://orcid.org/0000-0002-0262-762X

PhD, Sumy State University, Ukraine

Vladimira Krmelova

PhD, Associated Professor, Alexander Dubček University of Trenčín, Slovak Republic

Jan Krmela, ORCID ID: https://orcid.org/0000-0001-9767-9870

PhD, Associated Professor, University of Pardubice, Czech Republic

Abstract

The article is devoted to finding ways to assess the quality of educational activities at the university through analogies between tangible (technical) and intangible systems. The approach to determining the level of technological readiness for implementation (TRL) was used as a tool to assess the level of development of the quality of education system. The abstract-logical method and the method of induction-deduction were used in the analysis of the causal relationship between the quality of education and the assessment of the technological level of development readiness. Bibliometric analysis was performed using SciVal and VOSviewer tools based on data from the scientific-metric databases Scopus and Web of Science. Based on bibliometric analysis, it was found that currently the TRL approach has not been used to describe the dynamic system of education quality, as it is not adapted to intangible systems. A link was also established between the search query technology readiness level and socio-economic indicators of technology implementation in industry.

The description of each level of technological readiness of development on the example of the system quality of education with consistent progress in the development of quality assurance system and a brief description of each level of the studied intangible system. An example of determining the technological level of development readiness using the NYSERDA calculator is given. The results of the work can be useful for universities that build an effective internal system of quality assurance in education as an algorithm for consistent transition between levels of readiness and the relevant indicators of a particular technological level.

Keywords: quality of education, socio-economic development, technological level of readiness, calculator, bibliometric analysis, knowledge transfer.

JEL Classification: I25, O32, P46.

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Introduction

Determining the level of readiness of various developments for implementation is a key step in confirming the feasibility of the process of knowledge and technology transfer. The type of roadmap for the development of technology according to the logical scheme strategy – tactics – operation depends on the level of readiness of development. At the same time, development readiness assessment is a tool that has so far been used to describe material (technical) objects, rather than systems that do not have physical elements. The analogy between the level of readiness of process control algorithms and the technological level of readiness of development for commercialization can be an effective tool for identifying the state of development of an intangible object at different stages of its life cycle. In this paper, an attempt is made to describe the levels of technological readiness for a dynamic system of quality of education at the university.

Literature Review

The description of technological levels of readiness of development for commercialization can take different forms, but the approach to formation is invariable: from an assessment of possibility of creation of development to its commercialization. Tables 1 and 2 give an example of a description of the technological levels of readiness for development with the definition of the characteristics of each level of readiness.

Table 1. Assessment of technology readiness (TR) and technology risk or unpreparedness (TU)

Risk levels	Development readiness levels	Readiness description	Confidence
0	9	Production is fully launched and the product is competitive	100%
1	8	Production is fully tested, approved and ready for launch	95%
2	7	Demonstration of pilot production at a low level	90%
3	6	Release of the product prototype, including testing in the user's work environment	80%
4	5	Prototype testing in the user's working environment	65%
5	4	Confirmation of serviceability of the finished prototype in the laboratory	45%
6	3	The first assessment of the effectiveness of the idea and technology	30%
7	2	Technological solutions formulation	12%
8	1	Obtaining basic principles	5%
9	0	Lack of concept formulation or basic idea	0%

Source: Mankins, 1995.

Despite the technical description of each of the levels of readiness, it should be noted that it is possible to draw analogies between the state of readiness of the technical object and various control systems. To do this, bibliometric analysis should determine whether there is a relationship between keywords related to the phrases technology readiness level and quality of education with the definition of socio-economic factors of such a relationship. The establishment of a cause-and-effect relationship between the TRL tool and the method of creating and implementing a quality assurance system can be done indirectly, through keywords (topics) and clusters of topics that relate to both of the above phrases.

Table 2. Detailed description of each level of development readiness

Level	Description
TRL 1. Basic Research: Initial scientific research has been conducted. Principles are qualitatively postulated and observed. Focus is on new discovery rather than applications. *Basic principles observed and reported*	Lowest level of technology readiness. Scientific research begins to be translated into applied research and development. Examples might include paper studies of a technology's basic properties.
TRL 2. Applied Research: Initial practical applications are identified. Potential of material or process to solve a problem, satisfy a need, or find application is confirmed. *Technology concept and/or application formulated.*	Invention begins. Once basic principles are observed, practical applications can be invented. Applications are speculative and there may be no proof or detailed analysis to support the assumptions. Examples are limited to analytic studies.

Table 2 (cont.). Detailed description of each level of development readiness

Level	Description
TRL 3. Critical Function or Proof of Concept Established: Applied research advances and early stage development begins. Studies and laboratory measurements validate analytical predictions of separate elements of the technology. *Analytical and experimental critical function and/or characteristic proof of concept.*	Active research and development is initiated. This includes analytical studies and laboratory studies to physically validate analytical predictions of separate elements of the technology. Examples include components that are not yet integrated or representative.
TRL 4. Lab Testing/Validation of Alpha Prototype Component/Process: Design, development and lab testing of components/processes. Results provide evidence that performance targets may be attainable based on projected or modeled systems. *Component and/or breadboard validation in laboratory environment.*	Basic technological components are integrated to establish that they will work together. This is relatively "low fidelity" compared to the eventual system. Examples include the integration of "ad hoc" hardware in the laboratory.
TRL 5. Laboratory Testing of Integrated/Semi-Integrated System: System Component and/or process validation is achieved in a relevant environment. *Component and/or breadboard validation in relevant environment.*	The fidelity of breadboard technology increases significantly. The basic technological components are integrated with reasonably realistic supporting elements so it can be tested in a simulated environment.
TRL 6. Prototype System Verified: System/process prototype demonstration in an operational environment (beta prototype system level). *System/subsystem model or prototype demonstration in a relevant environment.*	A representative model or prototype system, which is well beyond that of TRL 5, is tested in a relevant environment. Represents a major step up in a technology's demonstrated readiness.
TRL 7. Integrated Pilot System Demonstrated: System/process prototype demonstration in an operational environment (integrated pilot system level). *System prototype demonstration in an operational environment.*	Prototype near, or at, planned operational system. Represents a major step up from TRL 6, requiring the demonstration of an actual system prototype in an operational environment such.
TRL 8. System Incorporated in Commercial Design: Actual system/process completed and qualified through test and demonstration (pre-commercial demonstration). *Actual system completed and qualified through test and demonstration.*	Technology has been proven to work in its final form and under expected conditions. In almost all cases, this TRL represents the end of true system development. Examples include developmental test and evaluations of the system in its intended weapon system to determine if it meets design specifications.
TRL 9. System Proven and Ready for Full Commercial Deployment: Actual system proven through successful operations in operating environment, and ready for full commercial deployment. *Actual system has proven through successful mission operations.*	The actual application of the technology in its final form and under mission conditions, such as those encountered in operational test and evaluation. Examples include using the system under operational mission conditions.

Source: according to Technology readiness levels definitions and descriptions, Technology Readiness Level.

Methodology and research methods

The abstract-logical method and the induction-deduction method were used to analyze the relationship between the above phrases. Bibliometric analysis was performed using tools SciVal (https://www.scival.com/) and VOSviewer (https://www.vosviewer.com/) based on data from scientometric databases Scopus (https://www.scopus.com/) and Web of Science (https://www.webofscience.com/)

One of the working hypotheses of the research is the possibility of using the laws of development of technical systems and tools for their description for intangible objects, management systems, etc. This assumption is due

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to the fact that the level of technological readiness can be determined for various technological processes, which are actually algorithms and can be considered separately from the equipment.

Results

The bibliometric analysis with the establishment of a causal relationship between the phrases technological readiness and quality of education took place in two stages.

Stage 1. Creating keywords, topics, and clusters of topics on the phrase level of technological readiness (Fig. 1 and 2).

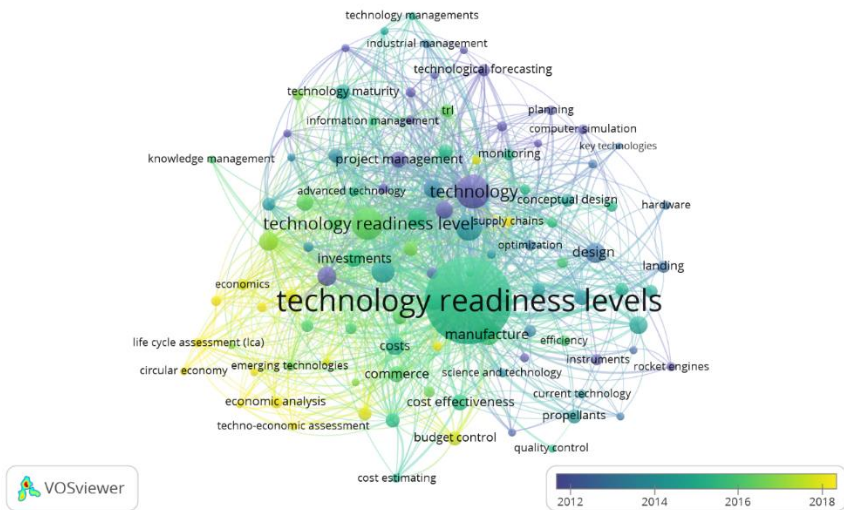


Figure 1. The results of building a map of keywords related to the query technology readiness level (data – database Web of Science, map construction tool VOS Viewer)

Source: developed by the authors.

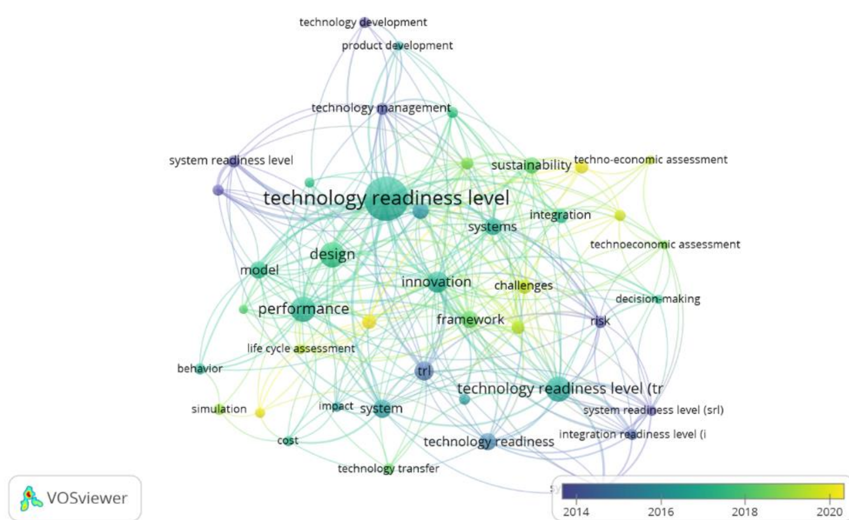


Figure 2. Results map of keywords related to technology readiness level (data – database Web of Science, map construction tool - VOSViewer)

Source: developed by the authors.

Using the bibliometric analysis tool VOSViewer, a comparative analysis of articles was downloaded from the Scopus database (almost 2,000 articles for the entire indexing period, keywords with a reference frequency of at least 10 times) and Web of Science (about 1,500 articles for the entire period indexing, keywords with a frequency of at least 5 times) by exact match in the title and / or annotation of the phrase technology readiness level.

The analysis of keywords related to a particular query has shown that there is no direct link between determining the technological level of development readiness and the quality of education. This fact can be explained by the fact that so far the system of quality of education has not been evaluated in terms of different levels of its readiness for implementation in general due to the lack of a universal approach to building such a system. In addition, the approach to assessing the level of readiness of intangible assets for implementation in the application of management systems for educational and scientific activities has not been applied so far. However, the indirect link between the TRL tool and the quality of education can be found indirectly through many keywords: innovation, decision making, challenges, techno-economic assessment, technology development and so on. In addition to the fact that these keywords can be a bridge between educational activities (quality of education) and the introduction of algorithms in the production (educational and scientific activities), they also describe the socio-economic impact of the degree of readiness for implementation. Confirmation of the latter thesis are the results of bibliometric analysis on topic by prominence and topic clusters by prominence, which are shown in Figure 3 and 4. As can be seen from the analysis of the list of topics and clusters of topics, the most popular are marketing strategies for their implementation, technology transfer, business university, etc. Thus, despite the lack of a cluster of quality of education in the results of search queries, it should be noted that the results of the quality assurance system of educational and scientific activities are directly relevant to the query technology readiness level. In addition, an important conclusion from the bibliometric analysis is the lack of attention to socio-economic indicators to assess the technological level of development readiness for implementation (Figure 5), as well as a relatively small share of scientific publications in social and behavioral sciences (Figure 6).

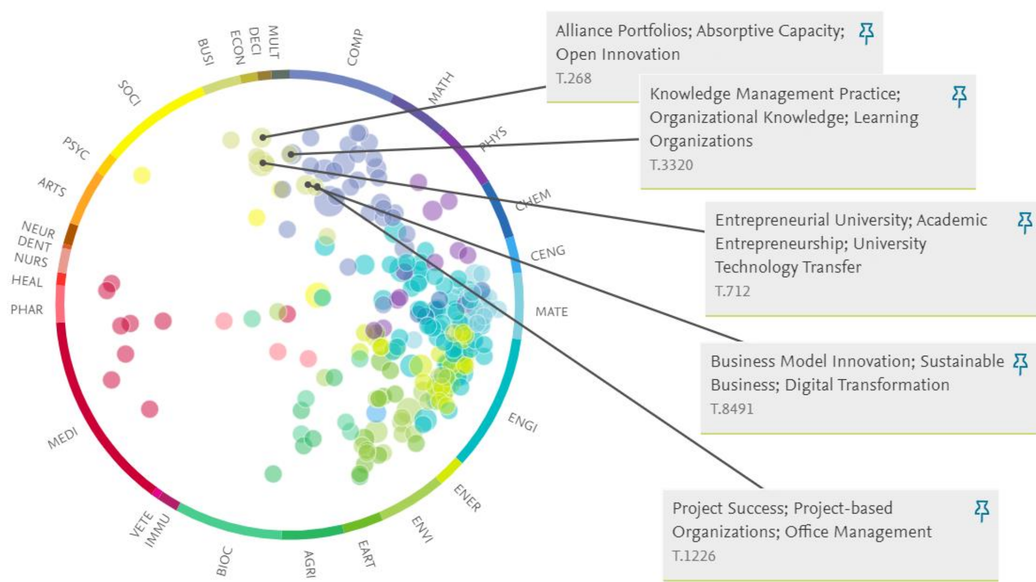
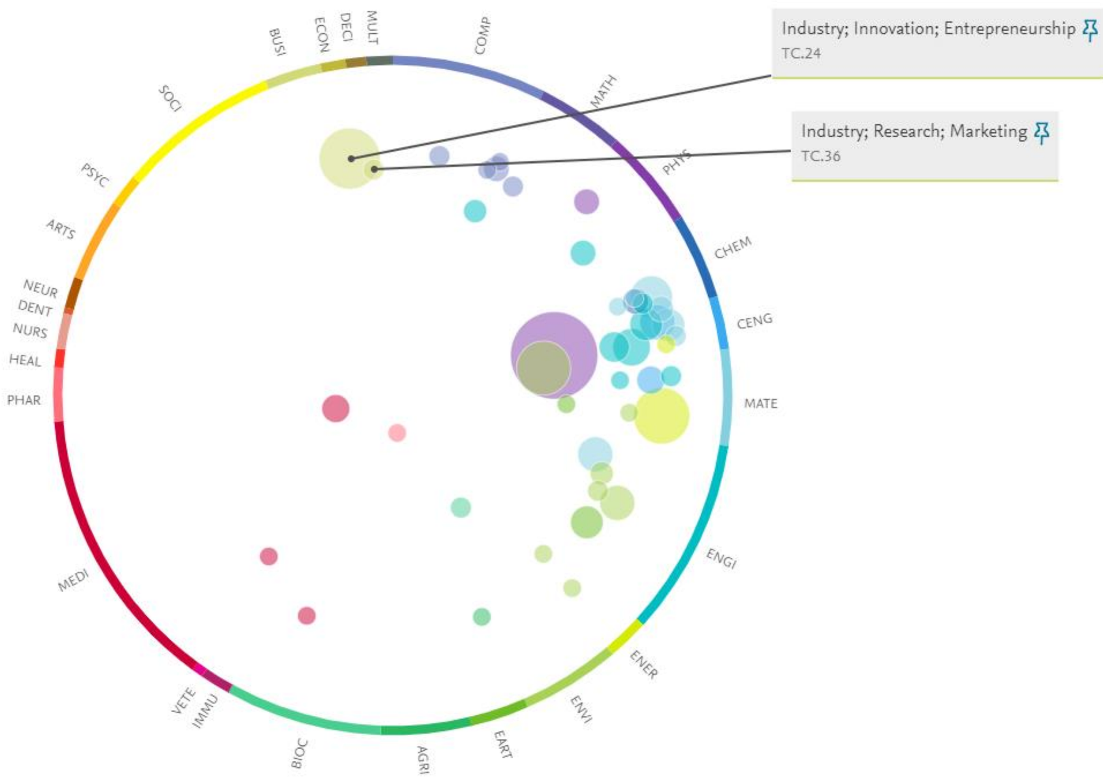
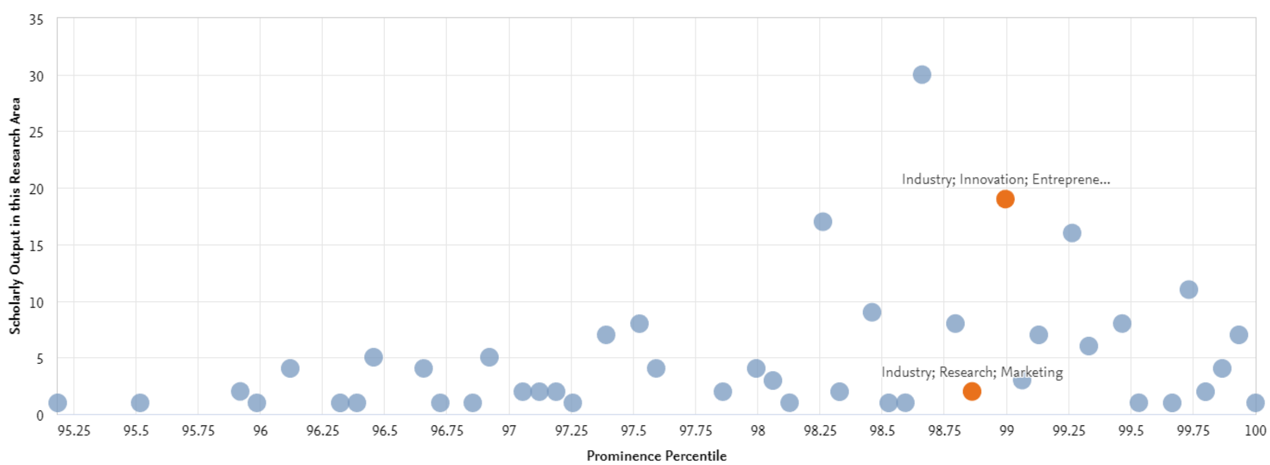


Figure 3. Topics of related areas of publishing activity on request technology readiness level (top 5% worldwide topic by prominence) (https://www.scival.com/)

Source: developed by the authors.



a



b

Figure 4. Clusters of publishing activity on request technology readiness level: a – top 5% worldwide topic clusters by prominence: b – prominence percentile (https://www.scival.com/)

Source: developed by the authors.

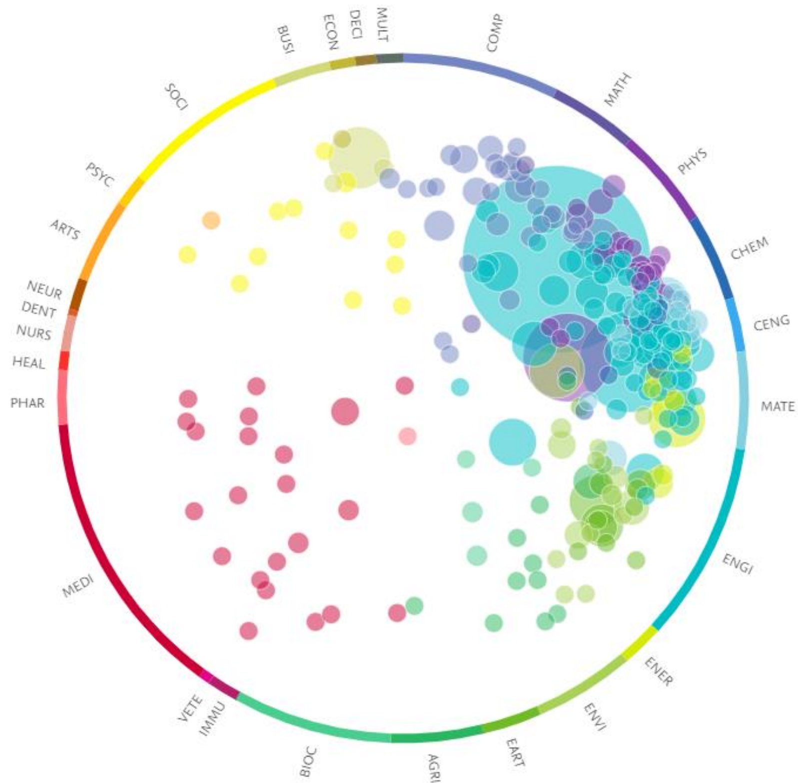
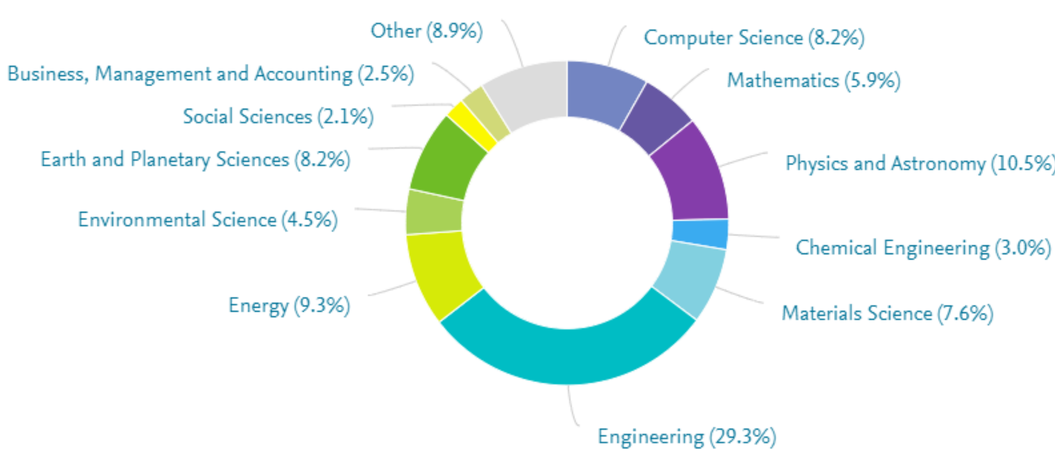


Figure 5. Topics of related areas of publishing activity on request technology readiness level (all topic clusters) (https://www.scival.com/)

Source: developed by the authors.

Step 2. Create a map of keywords, topics, and clusters of topics by phrase quality of education (Figure 7).

Using the bibliometric analysis tool VOSViewer, a comparative analysis of articles downloaded from the Scopus database (almost 5,000 articles for the entire indexing period), from which 731 articles were selected in the thematic areas of Business, Management and Accounting and Economics, Econometrics and Finance, keywords with a frequency of at least 10 times) by exact match in the title and / or annotation of the phrase quality of education.



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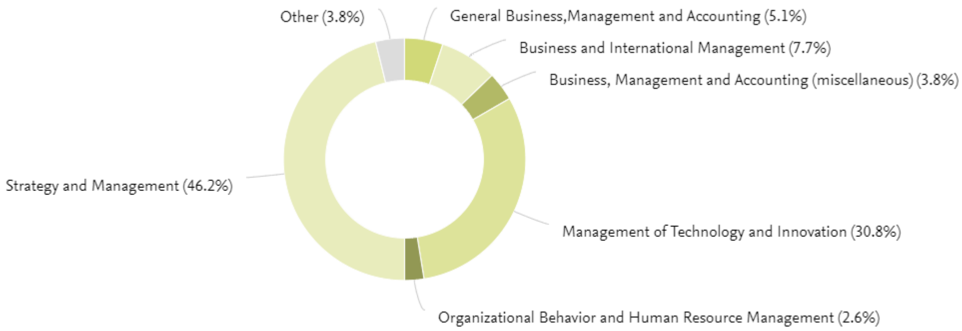

b

Figure 6. Topics of related areas of publishing activity on request technology readiness level: a – publications by Subject Area; b – detailed description of Subject Area "Business, Management and Accounting" (https://www.scival.com/)

Source: developed by the authors.

At this stage, based on the construction of a keyword map for the specified query, you need to know the keywords common to the previous query to build a logical connection between the studied phrases. It is interesting that the intersection of search queries is based on the keywords of the socio-economic sector, which indicates the possibility of describing tangible and intangible systems based on an assessment of their readiness. This conclusion can be a justification for the correctness of the approach proposed in this paper. Additional evidence for this thesis is a number of scientific papers (Dźwigoł, 2021; Edwards et al., 2017; Porev et al., 2016; Mazurkiewicz et al., 2017), which link the quality of education and innovative development in research. Thus, it is proved that the TRL tool can be used to describe intangible systems, in particular, the quality of education system. As an example, Figure 8 and Figure 9 provide an analysis of the technological level of readiness of the internal quality assurance system of higher education of Sumy State University, a detailed description of which is provided in the block of the regulatory framework of this educational institution (https://normative.sumdu.edu.ua/). The development of the author's team, which offers the interpretation of TRL 1 - TRL 9 in application to the dynamic system quality of education, is given in Table 2.

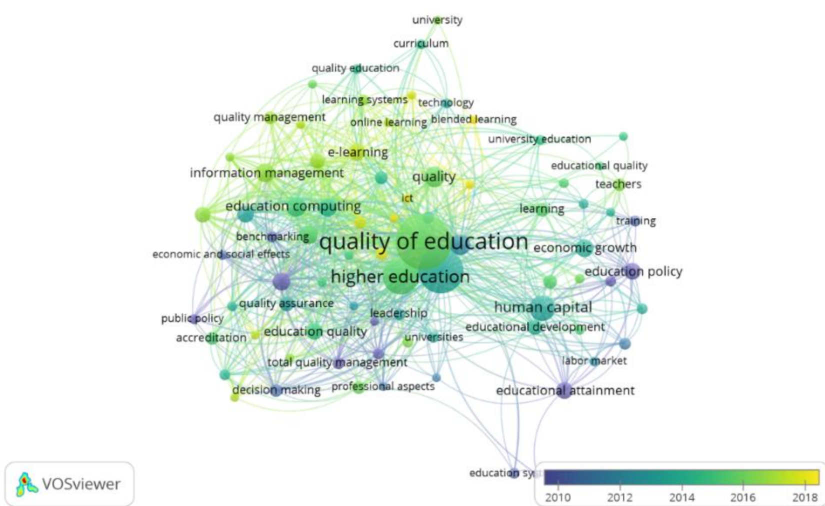

Figure 7. The results of building a map of keywords related to the query quality of education (data - DB Scopus, a tool for building a map - VOSViewer)

Source: developed by the authors.

NEW YORK STATE OF OPPORTUNITY. | NYSERDA

Technology & Commercialization Readiness Level Calculator

Instructions

This Excel Workbook has been developed by NYSERDA to help emerging and growing companies determine the level of technical and commercial maturity of their products/innovations through the use of a customized and integrated Technology Readiness Level (TRL) and Commercial Readiness Level (CRL) tool. This TRL/CRL tool is based on the systems developed by NASA, DOE, and ARPA-E, and has been designed specifically for ventures in the clean energy industry.

For each category, select the button next to the description that best fits the status of your product/innovation, this tool will determine the appropriate TRL and CRL levels based on your answers. Once all categories have been completed, go to "Summary & Results" tab to view your TRL and CRL scores and answers.

rendering any professional opinion or advice. You should consult with a professional advisor before taking any action based on the content of this tool.

Profile	
Company/Organization Name	Sumy State University
Proposal Title	Internal quality assurance system
Product/Innovation Description	

Technology		
○	1	Project work is beyond basic research and technology concept has been defined
○	2	Applied research has begun and practical application(s) have been identified
○	3	Preliminary testing of technology components has begun, and technical feasibility has been established in a laboratory environment
○	4	Initial testing of integrated product/system has been completed in a laboratory environment
◉	5	Laboratory scale integrated product/system demonstrates performance in the intended application(s)
Answer		**Laboratory scale integrated product/system demonstrates performance in the intended application(s)**

Product Development		
○	1	Initial product/market fit has been defined
○	2	Pilot scale product/system has been tested in the intended application(s)
○	3	Demonstration of a full scale product/system prototype has been completed in the intended application(s)
○	4	Actual product/system has been proven to work in its near-final form under a representative set of expected conditions and environments
◉	5	Product/system is in final form and has been operated under the full range of operating conditions and environments
Answer		**Product/system is in final form and has been operated under the full range of operating conditions and environments**

Product Definition/Design		
○	1	One or more initial product hypotheses have been defined
○	2	Mapping product/system attributes against customer needs has highlighted a clear value proposition
○	3	The product/system has been scaled from laboratory to pilot scale and issues that may affect achieving full scale have been identified
◉	4	Comprehensive customer value proposition model has been developed, including a detailed understanding of product/system design specifications, required certifications, and trade-offs
○	5	Product/system final design optimization has been completed, required certifications have been obtained, and product/system has incorporated detailed customer and product requirements
Answer		**Comprehensive customer value proposition model has been developed, including a detailed understanding of product/system design specifications, required certifications, and trade-offs**

Competitive Landscape		
○	1	Secondary market research has been performed and basic knowledge of potential applications and competitive landscape have been identified
○	2	Primary market research to prove the product/system commercial feasibility has been completed and basic understanding of competitive products/systems has been demonstrated
○	3	Comprehensive market research to prove the product/system commercial feasibility has been completed and intermediate understanding of competitive products/systems has been demonstrated
◉	4	Competitive analysis to illustrate unique features and advantages of the product/system compared to competitive products/systems has been completed
○	5	Full and complete understanding of the competitive landscape, target application(s), competitive products/systems, and market has been achieved
Answer		**Competitive analysis to illustrate unique features and advantages of the product/system compared to competitive products/systems has been completed**

Team		
○	1	No team or company in place (single individual, no legal entity)
○	2	Solely technical or non-technical founder(s) running the company with no outside assistance
○	3	Solely technical or non-technical founder(s) running the company with assistance from outside advisors/mentors and/or incubator/accelerator
◉	4	Balanced team with technical and business development/commercialization experience running the company with assistance from outside advisors/mentors
○	5	Balanced team with all capabilities onboard (e.g. sales, marketing, customer service, operations, etc.) running the company with assistance from outside advisors/mentors
Answer		**Balanced team with technical and business development/commercialization experience running the company with assistance from outside advisors/mentors**

Go-To-Market		
○	1	Initial business model and value proposition have been defined
○	2	Customers/partners have been interviewed to understand their pain points/needs, and business model and value proposition have been refined based on customer/partner feedback
○	3	Market and customer/partner needs and how those translate to product requirements have been defined, and initial relationships have been developed with key stakeholders across the value chain
◉	4	Partnerships have been formed with key stakeholders across the value chain (e.g. suppliers, partners, service providers, and customers)
○	5	Supply agreements with suppliers and partners are in place and initial purchase orders from customers have been received
Answer		**Partnerships have been formed with key stakeholders across the value chain (e.g. suppliers, partners, service providers, and customers)**

Manufacturing/Supply Chain		
○	1	Potential suppliers, partners, and customers have been identified and mapped in an initial value chain analysis
○	2	Relationships have been established with potential suppliers, partners, service providers, and customers and they have provided input on product and manufacturability requirements
◉	3	Manufacturing process qualifications (e.g. QC/QA) have been defined and are in progress
○	4	Products/systems have been pilot manufactured and sold to initial customers
○	5	Full scale manufacturing and widespread deployment of product/system to customers and/or users has been achieved
Answer		**Manufacturing process qualifications (e.g. QC/QA) have been defined and are in progress**

Figure 8. Analysis of the technological level of readiness of the internal quality assurance system of higher education of Sumy State University (calculator NYSERDA)

Source: developed by the authors.

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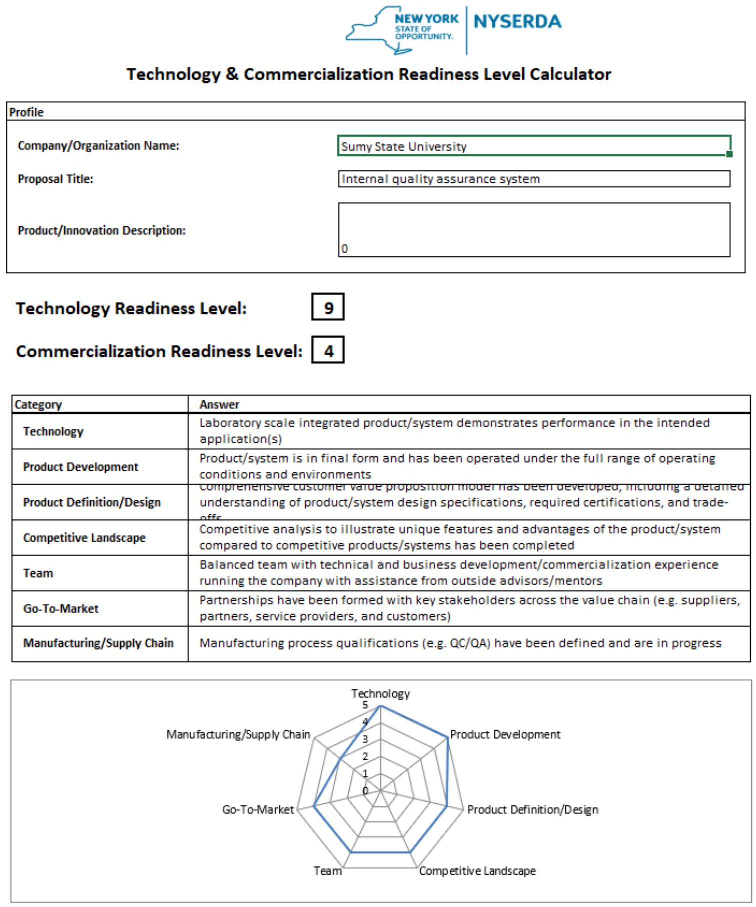

Figure 8. Results of the analysis of the technological level of readiness of the internal system of quality assurance of higher education of Sumy State University (calculator NYSERDA)

Source: developed by the authors.

Table 2. The readiness assessment of the education system quality

Development readiness levels	Readiness description
9	Scaling the system to other universities
8	Institutional accreditation
7	Accreditation, a positive decision of an independent agency to ensure the quality of education
6	Collection of feedback from external stakeholders
5	Assessment of the level of system socio-economic impact
4	Verification of the developed mechanisms efficiency and algorithms
3	Regulatory framework implementation
2	Regulatory framework development
1	Review of successful world practices
0	Determining the urgent need to develop a quality assurance system for education

Source: developed by the authors.

Conclusions

The description of each level of technological readiness of development on the example of the system quality of education with consistent progress in the development of quality assurance system and a brief description of each level of the studied intangible system. An example of determining the technological level of development readiness using the NYSERDA calculator is given. The results of the work can be useful for universities that build an effective internal system of quality assurance in education as an algorithm for consistent transition between levels of readiness and the relevant indicators to ensure a specific technological level.

Author Contributions: conceptualization, A.A. and I.V.; methodology, I.V.; software, A.A.; validation, A.A., I.V., J.K. and V.K.; formal analysis, J.K. and V.K.; data curation, I.V.; writing-original draft preparation, A.A.; writing-review and editing, A.A., J.K. and V.K.; visualization, I.V.; supervision, A.A.; project administration, A.A.

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