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Ranking Analysis of Production Engineering Courses Against Industry 4.0

Análise de Ranking dos Cursos de Engenharia de Produção Frente à Indústria 4.0

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ABSTRACT

In the midst of changes related to Industry 4.0, the preparation of engineers is essential. Thus, this paper aims to point out the effectiveness of evaluation instruments of Brazilian universities or courses to portray the adequacy of production engineers' training to the needs of production methods for Industry 4.0. This paper analyzes two systems: the ENADE, an official evaluation of higher education, and the RUF, a university ranking applied by a large Brazilian newspaper. ENADE intends to evaluate the absorption of specific program content in accordance with national guidelines, in addition to the assessment of general knowledge related to contemporary issues of social and economic impact; it is mandatory and applied throughout the National territory. The RUF is an annual assessment of Brazilian higher education and is subdivided by institutions and courses. As a result, it was identified that the joint application of these two systems promotes a reading of the adequacy of the courses to industry 4.0.

Keywords: Evaluation. Effectiveness. Ranking. Brazil.

RESUMO

Em meio às mudanças relacionadas à Indústria 4.0, a preparação dos engenheiros é essencial. Assim, este trabalho tem como objetivo apontar a eficácia dos instrumentos de avaliação das universidades ou cursos brasileiros para retratar a adequação da formação dos engenheiros de produção às necessidades dos métodos de produção para a Indústria 4.0. Este artigo analisa dois sistemas: o ENADE, avaliação oficial do ensino superior, e o RUF, ranking universitário aplicado por um grande jornal brasileiro. O ENADE pretende avaliar a absorção de conteúdos programáticos específicos de acordo com as diretrizes nacionais, além da avaliação de conhecimentos gerais relacionados a questões contemporâneas de impacto social e econômico; é obrigatório e aplicado em todo o território nacional. O RUF é uma avaliação anual do ensino superior brasileiro e é subdividido por instituições e cursos. Como resultado, identificou-se que a aplicação conjunta desses dois sistemas promove uma leitura da adequação dos cursos à indústria 4.0.

Palavras-chave: Avaliação. Eficácia. Classificação. Brasil.

1 INTRODUÇÃO

Industry 4.0 is more than the implantation of technology; it is also about having trained personnel, adequate culture, and instruments (human and technological) to absorb change, which is increasingly present and profound. So, as an essential point of this new production matrix, engineers must master different aspects of the operation process design and management, both technology and human-based.

Preparing new professionals for these activities demands knowing the industry transformation scenario. Industry 4.0, the predetermined operating environment for future engineers, provides the digitization and aggregation of technological procedures that cover the entire production network, as well as after-sales services (TURKYILMAZ *et al*., 2021). This digital transformation allows new productive dynamics, with the possibility of manufacturing customized products in a large-scale process.

Moreover, combining production machines with computational technologies enables the complete system, including employees, to transmit information efficiently within all supply chains, shrinking costs (BOROWSKI, 2021). Table 1 condenses an overview of selected technologies according to their occurrence in individual key studies. These technologies are the most critical ones, identified with a significant impact on the economy over the next ten years (LACIOK *et al*., 2021).

Table 1 - Selected technologies overview

Technologies	
Artificial Intelligence	Cloud Computing
Blockchain	Smart electrical network
Internet of Things	Communication between machines
Augmented reality	Advanced production
Virtual reality	Interface human-machine
Robotics	Advanced storage energy
3D printing	Nanomaterials
Drones	Nanotechnologies
Big data	Autonomous automobiles
Cyber security	Advanced production

Source: Laciok *et al*., 2021.

Analyzing the Industry 4.0 concept, Frank *et al*. (2019) organizes technologies into two layers: one comprises the technologies related to their front-end purpose, named Front-end technologies; the other includes the base technologies that permit the connectivity and the intelligence of the Front-end technologies. This organization is helpful to understand the application of the technologies of which engineers should have a thorough understanding. On the other hand, the Front-end layer comprises four areas: Smart Manufacturing, that is, the operational process transformation and management; Smart Product, meaning the design of connected products; Smart Supply Chain, considering the acquisition and delivery of raw materials and products; and Smart Working, concerning the planning of the way the work will change.

To summarize, Industry 4.0 can be understood as the use of technological devices that combine production equipment with computational technologies and the pro-duction process organization, aiming at improving flexibility, customization, and efficiency. The industry 4.0 organization demands technical and human competencies development to design, implement, operate, and maintain its complex operating system. It can be seen, then, that there are a set of modifications that become increasingly necessary, changing not only production technologies but also the way people work within companies. Therefore, the transformation towards a digitalized production process depends on workforce qualification and technical personnel recruitment.

To meet the progressive demand for technical workers, several engineering schools are redesigning their curricula tailored for Industry 4.0, increasing trend points such as Cyber Physical Systems, virtualization, robotics, and advanced computing tools (Sahman et al., 2019). However, it is still hard to identify the course fit to the industry 4.0 demands. Thus, this paper analyses two evaluation systems of Brazilian universities or courses to portray the adequacy of production engineers' training to the needs of the industry 4.0 context.

The central assumption of this investigation is that engineering courses influence the profile of the graduates regarding technical knowledge, mindset, and worldview. Thus, the evaluation systems are analyzed considering if they contemplate the three aspects.

2 CONTEXT AND THEORETICAL BACKGROUND

The development and implementation of technologies are part of technicians and engineers' jobs, who, therefore, need to master the technological environment of Industry 4.0. The engineering schools are supposed to accommodate this knowledge, and, for a permanent and official change, it is necessary that the course evaluation instruments also adapt to the new reality.

The following subsections present two evaluation systems – an official system carried out by the Brazilian Ministry of Education and the University ranking applied by a Brazilian newspaper.

2.1 ENADE – Students' Performance National Exam

In Brazil, a periodic evaluation named ENADE is carried out by the Brazilian Ministry of Education to identify whether higher education schools respond to existing market demands. ENADE is a large-scale assessment of undergraduate systems, applied every three years to all courses of some areas of knowledge (with their courses/qualifications). The results of ENADE / 2019, from the Production Engineering Area, present, in addition to the quantitative measurement of the student's performance in the test, qualitative indicators of their economic and social conditions (INEP, 2020).

As for the quantitative measurement, the ENADE aims to measure students' performance on the contents provided in the curriculum guidelines of the undergraduate areas, the skills needed to adapt to the evolution of the knowledge, and skills to understand the professional cross-cutting issues (INEP, 2020).

The analysis reports of the production engineering ENADE / 2019 maintained, in principle, the structure adopted in the previous exams. Among these, the following stand out: (i) a specific report on the performance of the different Areas in the General Training test; (ii) an analysis of the profile of the course coordinators; (iii) an analysis of the perception of course coordinators and students about the training process during graduation; (iv) an analysis of the linguistic performance of the graduates, based on the discursive answers in the General Formation test; and (v) a separate analysis for face-to-face and distance courses (when applicable). In addition, the ENADE was applied to students of engineering courses that were expected to be concluded by July 2020.

More broadly, this type of evaluation also supports decisions about public investments in Higher Education, the adequacy of national guidelines, and the general policies of the body of directors of educational institutions. Therefore, decision-makers in higher education schools tend to use ENADE's analysis axes to guide the strategies of pedagogical projects and other aspects of educational institutions. Moreover, from the students' point of view, they are interested in the outstanding performance of the institution, whose name they will carry through their professional life.

Hence, the ENADE's capacity to evaluate the compatibility of the courses with Industry 4.0 principles can enable a faster transformation of engineers' courses to-wards the new paradigm.

2.2 RUF – University Ranking of Folha de São Paulo

The major known international university rankings include Times Higher Education World University Rankings, QS World University Rankings and Academic Ranking of World Universities (ARWU)(WIECHETEK and PASTUSZAK, 2022). The Times Higher Education lists 1,400 universities in 92 countries and measures the performance of institutions on criteria such as teaching, research, knowledge transfer, and international outlook (TIMESHIGHEREDUCATION, 2020).

The Folha de São Paulo newspaper ranks Brazilian schools along the lines of these global rankings and publishes the RUF, a university ranking that evaluates schools, including the ones that do not enter the international level.

This assessment is carried out annually, covering 196 Brazilian universities, public and private. The RUF takes into account five references: Education, Market, Re-search, Innovation and Internationalization.

The ranking assesses market adequacy through interviews carried out with Human Resources professionals from companies of different natures. Research on the innovation aspect covers patents and partnerships with companies and, in terms of inter-nationalization, evaluate international citations by professors and publications in international co-authorship. Finally, the research framework analyzes published articles and quotes from professors, in addition to their evaluation by research funding agencies. In addition to Universities, the RUF also evaluates 40 degrees of Universities, Colleges and University Centers with the highest number of entrants in the country according to the latest Higher Education Census available and, therefore, Production Engineering courses are evaluated in this classification (RUF, 2019).

This paper discusses the training of production engineers and whether the assessment tools of the schools that prepare them are adapting to new education/training proposals. It is assumed that assessment instruments, whether administered by government agencies or the rankings of independent media, by making public any inadequacies in the practices of training professionals with solid analyzes, can shape the educational strategies of schools.

3 METHODOLOGY

About the research methodology, this study has a descriptive purpose, given that its primary objective is to describe the characteristics of a given population or phenomenon or establish relationships between variables (MOSAVI *et al*., 2018).

Some descriptive research goes beyond identifying relationships between variables, aiming to determine the nature of that relationship, and, in this way, coming close to an explanatory investigation. On the other hand, there are studies that, although de-fined as descriptive based on their objectives, end up serving more to provide a new view of the problem, which brings them closer to exploratory research. Descriptive research is, along with the exploratory ones, the one that social researchers usually carry out with a view to practical action.

This research seeks a new view of the problem, as explained above, based on bibliographic and documentary research. Firstly, it was searched national publications on ENADE, using the CAPES journal basis with the keywords in Portuguese: ENADE, educational Census, and evaluation of courses. Within the search scope, these ex-pressions provided the satisfactory return rate for the construction of the analysis.

A second search was made on the industry 4.0 and education, as well as on the rankings of universities. For this search it was used the Web of Science and Scopus bases. The search for Industry 4.0 aimed to identify the profile of the Engineer suitable for this production model, as well as aspects of his training; for that, it was used the keywords: professional profile of the engineer, engineering education. To search for publications on the teaching of engineers for Industry 4.0, it was used the key-words: Industry 4.0, production engineering, professionalism in the labor market. The most cited texts were selected, and the abstracts were read to choose those that sup-ported this research about the Production Engineering course. This area is chosen because it is indelibly integrated into the production systems, the central point of debate in Industry 4.0.

In addition to the bibliographic research, a documental investigation about the ENADE examination and the RUF ranking was realized. This investigation used the following documents: Area Synthesis Report - Production Engineering and the School Census 2019, available on the site http://portal.inep.gov.br/web/guest/ results-and-summaries. The study searched the online records for the performance reports of production engineering courses and the examinations carried out from 2012 to the present date.

The Folha University Ranking - RUF references are available at https://ruf.folha.uol.com.br/2019/, where the study looked for the dimensions and indicators used and the procedures for their construction.

4 RESULTS AND ANALYSIS

Schislyaeva *et al.* (2022) establish that industry 4.0 is qualified by the use of cyber-physical systems in production processes. It should be noted that these systems will be connected to a network, will talk to each other, will self-adjust and will learn new operating models.

Industry 4.0 has gained a leading role in industrial design and is causing profound changes in production engineering. However, to respond to the industry 4.0 design, an essential foundation must be available, both technical and human. Therefore, necessary action is to reconcile the educational structure to this new way of producing, with special attention to engineering education (COSKUN *et al*., 2019).

The author highlights a tripod that supports the differentiated course to prepare young people to work in Industry 4.0. The first pillar is focused on the curriculum, which covers the technical areas for industry 4.0, including an interdisciplinary project. For this project, the teachers should gather students from different degrees and various courses. This inclusion is key in integrated learning and, with a systemic focus, a condition for the performance of a technological production structure. In addition, the curriculum reinforces the disciplines of statistical analysis and computer systems, as computer technology is the basis of the fourth industrial revolution. The second pillar is the activities and use of laboratories. These are important pieces in the proposal, as they provide practical knowledge through simulated and monitored experiences supervised by the teachers. In addition, the laboratory projects can help the learner understanding the production process while improving the operating skills of new technologies. Finally, the third pillar is scenario-based learning, which uses real problems to promote knowledge acquisition in which the student plays a leading role (COSKUN *et al.*, 2019). Thus, these authors combine the learning of technical content with the need for some essential social skills for constant development during professional life.

Likewise, Erol *et al*. (2019) argue that the industry 4.0 professional must have social and interaction skills to participate and lead interdisciplinary projects, as the teams are composed of a range of professionals from different backgrounds and experiences. For this reason, having socializing tools becomes essential for the engineer in this environment.

Consequently, it would be necessary to understand how schools offering production engineering courses adapt their services to meet these demands. The challenge that lies ahead is how to assess the ability of schools to develop skills that address the social dimension.

Marik (2016) draws attention to the fact that the fourth Industrial Revolution is a fundamental change in people's thinking rather than a modification in technology. As a result, a number of new education requirements are placed on universities, which will, in turn, have to change the content and style of teaching at the burden of additional economic investments. In short, these movements point towards education, which will have to face a significant change in the way students learn and are evaluated. Moreover, engineering schools will have to invest in laboratories and equipment, and the most critical is the training of professors and mentors.

Graduating students will have to be proactive, have independence and seek knowledge, which will come from actual experiences that influence students to dis-cover, research, propose, question, and problematize (MIQUILIM and SILVA, 2019).

However, some authors point out that even though there is an effort to mold engineering schools to the demands of the current moment, several gaps remain to be solved. For example, Carvalho and Tonini (2017) understand that the current engineering courses incorporate many competencies in their curricula requested by traditional industries, while some critical characteristics of the new engineer are still absent. The main aspects mentioned by the authors are related to people management, a feature investigated in detail in their work.

4.1 Rankings and Industry 4.0

Decuypere and Landri (2021) rankings do not only measure educational performance, but they also provide status, as well as enhance competition between institutions.

Lukman et al. (2010) also highlight that one of the purposes of measurement through rankings is the perception of quality gaps in schools that offer higher education, helping them improve their service. Moreover, each adaptation developed to adjust to the current requirements can be assessed concerning the whole concept of the professional profile, which is key to reaching the job market's fit.

Therefore, these evaluations permit a vision that makes it easier to ponder the courses' weaknesses, strengths, and opportunities, being a helpful tool for strategic change (LUKMAN *et al.*, 2010). So, considering the need to verify the suitability of this professionals for the job market, a query to be posted is whether the rankings are structured and executed to indicate the best professional trainers for the industry 4.0.

Initially, what can be seen among the rankings presented is that there are many similarities between them in the topics observed, since the RUF uses ENADE data to start its application, but the calculation equalized by the Folha de S. Paulo newspaper extends to variables more consistent with the real desire of the industry, as in addition to taking into account the aspects of teaching, research, internationalization, it is also attentive to the development of innovations, and this point is fundamental in the current industry, in addition to verifying how the market judges professionals "manufactured" in these courses.

It should be noted that the RUF meets some points highlighted by Erol *et al*. (2016) e Coskun *et al*. (2019) as it seeks to point out which courses provide professionals with problems' solving capacity, such as those who have social resourcefulness de-manded by team working and networking.

4.2 ENADE and Industry 4.0

The assessments applied to the Production Engineering course were accessed from 2012, the year that the term industry 4.0 was coined for the first time. In this period (2012 to 2019) three exams were performed, the years of application were 2014, 2017, and 2019.

In 2014, a question (out of a total of 40) was found on the concept of innovation, which is important for Industry 4.0, as pointed out by Bonilla *et al.* (2018), though not exclusive. Also, as observed by the authors, the concept of sustainability was found in all the evaluated exams. The 2017 test does not appear to have questions that converge to the "universe" of industry 4.0. Already in the year 2019, five questions (out of 40) are related to the content discussed by authors dealing with industry 4.0 (EROL *et al*., 2016 e COSKUN *et al.*, 2019): Additive Manufacturing, Internet of Things, Technology and Artificial Intelligence.

It is noteworthy that there were no questions that evoked important points about knowledge and skills related to the development of the concept of leadership. In addition, it is observed that the exams also did not perform the analyzes that stand out: Block Chain, augmented reality, virtual reality, robotics, Drones and big data.

It is noteworthy that the evaluations do not monitor the quality of the laboratories available in the institutions, this non-supervision ends up compromising the reading of the training of professionals who graduated from the courses, Ferreira *et al*. (2020), highlights that laboratories improve the capabilities of future professionals who will work in organizations, therefore, being essential in the construction of technical training, an observation made in the work of Erol *et al*. (2016) and Coskun *et al*. (2019).

It is also noteworthy that despite some gaps, as defended above, ENADE assesses interdisciplinarity, an important focus for Coskun *et al.* (2019), as revealed by some exam questions that have sustainability at their heart. The exam also asks questions about the use of technologies, a key point in industry 4.0, but does not develop aspects that Erol *et al.* (2016) address as relevant, these points being a list of skills that are: personal skills, social skills, action skills and mastery skills, points of social and personal dimension. In this case, the RUF can develop this assessment, by using data that the market makes available as information that includes the notes defended by Erol *et al.* (2016).

5 CONCLUSIONS

To summarize, the courses must transform themselves to face a period of intense changes, and the rankings are beacons for possible decision-making.

The results show that the two evaluations are related to essential aspects of Industry 4.0 but leave gaps that must be completed. For example, the evaluations cannot verify the training of leaders, which is a vital requirement acknowledged by the literature. Moreover, the approaches inherent to the sociability of professionals are not assessed either, though engineers are no longer "just" technicians; they are also managers. The challenge of evaluating soft skills can justify those restrictions. Still, the ability to lead and participate in teams is an inevitable condition, and the schools should care for its development.

It is understood, therefore, that the RUF incorporates the market assessment, and this is positive. Still, in contrast, it does not have the impact that ENADE has since the evaluation carried out by INEP is a state policy. Its performance throughout the national territory is required, and in many cases, higher education institutions tailor their content exhibition to that requested by the referred exam. This evaluation covers a set of concepts, including the students' grades average, as parameters for the results.

It is noteworthy that an assessment model that sums up the main points of each exam would improve the evaluation of the training for the industry 4.0 production model.

REFERENCES

BONILLA, S. H *et al.* (2018). Industry 4.0 and sustainability implications: A scenario-based analysis of the impacts and challenges. Sustainability, 10(10), 3740.

CARVALHO, L. D. A; TONINI, A. M. (2017). Uma análise comparativa entre as competências requeridas na atuação profissional do engenheiro contemporâneo e aquelas previstas nas diretrizes curriculares nacionais dos cursos de Engenharia. Gestão & Produção, 24, 829-841.

Como é feito o Ranking Universitário Folha. RUF, 2019. Disponível em: <https://ruf.folha.uol.com.br/2019/noticias/como-e-feito-o-ranking-universitario-folha.shtml>. Acesso em: 17 de mar.de 2021.

COŞKUN, S; KAYIKCI, Y; GENÇAY, E. (2019). Adapting engineering education to industry 4.0 vision. Technologies, 7(1), 10.

EROL, S *et al.* (2016). Tangible Industry 4.0: a scenario-based approach to learning for the future of production. Procedia CiRp, 54, 13-18.

FERREIRA, P. J. G *et al.* (2020). INDÚSTRIA 4.0: MODELO DE ENSINO PARA FORMAÇÃO DE ENGENHEIROS DE PRODUÇÃO. Revista de Ensino de Engenharia, 38(3).

INEP Instituto Nacional de Estudos e Pesquisas Educacionais Anisio Teixeira, Resultados ENADE 2019, Conceito ENADE e IDD 2019, Brasília, outubro 2020. PowerPoint Presentation (inep.gov.br).

LUKMAN, R; KRAJNC, D; GLAVIČ, P. (2010). University ranking using research, educational and environmental indicators. Journal of cleaner production, 18(7), 619-628.

LACIOK, V., Sikorova, K., Fabiano, B., & Bernatik, A. (2021). Trends and Opportunities of Tertiary Education in Safety Engineering Moving towards Safety 4.0. Sustainability 2021, 13, 524.

MAŘÍK, V. (2016). Průmysl 4.0: výzva pro Českou republiku. Management Press.

MIQUILIM, D; DA SILVA, M. T. (2019). The teaching of innovative entrepreneur engineers: key factors that contribute to teaching-learning processes and university management. The International journal of engineering education, 35(5), 1480-1492.

MOSAVI, A; OZTURK, P; CHAU, K. W. (2018). Flood prediction using machine learning models: Literature review. Water, 10(11), 1536.

SAHMAN, H *et al.* Survey of Engineering Students' Cognitive Level of Industry 4.0.

WIECHETEK, Ł; PASTUSZAK, Z. Academic social networks metrics: an effective indicator for university performance?. Scientometrics, p. 1-21, 2022.

SCHISLYAEVA, E. *et al*. Integrated Estimation of a Cyber-Physical System's Sustainability. Energies, v. 15, n. 2, p. 563, 2022.

DECUYPERE, M; LANDRI, P. Governing by visual shapes: University rankings, digital education platforms and cosmologies of higher education. Critical Studies in Education, v. 62, n. 1, p. 17-33, 2021.

BOROWSKI, P. F. Digitization, digital twins, blockchain, and industry 4.0 as elements of management process in enterprises in the energy sector. Energies, v. 14, n. 7, p. 1885, 2021.

FRANK, A. G; DALENOGARE, L. S; AYALA, N. F. Industry 4.0 technologies: Implementation patterns in manufacturing companies. International Journal of Production Economics, v. 210, p. 15-26, 2019.

World University Rankings 2020. timeshighereducation, 2020. Disponível em: <https://www.timeshighereducation.com/world-university-rankings/2020/world-ranking#!/page/0/length/25/sort_by/rank/sort_order/asc/cols/stats>. Acesso em: 17 de mar.de 2020.

TURKYILMAZ, A *et al*. Industry 4.0: challenges and opportunities for Kazakhstan SMEs. Procedia CIRP, v. 96, p. 213-218, 2021.

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