RESEARCH ARTICLE

A Framework for Assessing Higher Education Courses Employability

HERBERT SALAZAR DOS SANTOS[1], **YURI OLIVEIRA DE LIMA**[1],
CARLOS EDUARDO BARBOSA[1,2], **ALAN DE OLIVEIRA LYRA**[1],
MATHEUS MARGARIDO ARGÔLO[1], **AND JANO MOREIRA DE SOUZA**[1], **(Member, IEEE)**

[1]Graduate School and Research in Engineering (COPPE), Centro de Tecnologia—Rua Horácio Macedo, Cidade Universitária da Universidade Federal do Rio de Janeiro, Rio de Janeiro 21941-450, Brazil
[2]Center of Analysis of Naval Systems (Brazilian Navy) (CASNAV), Rio de Janeiro 20091-000, Brazil

Corresponding author: Herbert Salazar Dos Santos (herbertsds@cos.ufrj.br)

ABSTRACT The 4th Industrial Revolution is causing profound and accelerated changes to work, bringing new opportunities and challenges as new technologies impact practically all occupations. The transformations in the labor market were accelerated even more due to the COVID-19 pandemic. In the scenario where old careers cease to exist, and new occupations are being created, Higher Education Institutions (HEIs) need to be prepared to educate professionals capable of getting and keeping qualified jobs. To do so, HEIs need tools to evaluate their undergraduate courses in the face of the changing demands of the labor market. We propose a novel approach to employability from the perspective of HEIs, creating a framework – called Higher Education Courses Employability (HECE). The framework can help HEI decision-makers to make decisions based on employability data. The framework allows for mitigating the reported gap between the theory taught in HEIs and the labor market demands. We evaluated the HECE framework as useful and relevant by HEI decision-makers and Employability experts from Brazil, a continental country with great social differences between and within its regions, and where the unemployment and underemployment rates demonstrate the mismatch between the labor market demands and the undergraduate course's curricula. The applicability of HECE in different Brazillian regions provides evidence that we can apply the framework in most contexts. This study provides tools to facilitate the implementation of the framework by HEIs. The evaluators reported the innovative nature of the approach of this research.

INDEX TERMS Employability, higher education, HEIs, undergraduate employability, courses employability.

I. INTRODUCTION

Concerns about the future of employment are not new. Two centuries ago, the idea of new technologies replacing the human workforce made a group of textile workers destroy textile machinery – a movement known as Luddites [1]. Nowadays, the 4th Industrial Revolution brings new questions about the future with the advance of Artificial Intelligence, biotechnology, and nanotechnology. This advance accelerates changes to work and brings new concerns about

technological unemployment [2], [3], which occurs when the number of jobs lost for technology is greater than the capability of that workforce to be reallocated in the labor market [4]. The COVID-19 pandemic made unemployment concerns more critical, with unemployment rates comparable to the Great Recession, accelerating the changes in the labor market [5].

In this context, workers seek more qualifications to increase their employability – i.e., the personal capability to obtain and keep a job [6]. However, people avoid spending time and money on education in a recession, especially if this education does not convert into an increase in income [7].

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Therefore, synergy with the labor market demands is crucial for Higher Education Institutions (HEIs) relevance [8], [9], [10]. In the United States, undergraduates see the wage premium – the difference between the average salary of graduates versus school leavers – decreasing, causing higher education enrollments to decrease by 8% [7]. The Institute for Fiscal Studies (IFS) estimates that 20% of British students would be more financially successful if they were not graduated [11]. HEIs need, though, to develop strategies to increase their employability – and their relevance [12], [13], [14].

HEIs may use institutional and labor market indicators to support decision-making concerning course portfolio improvements, course curricula, and teaching staff qualifications. Indicators can enable HEIs to assess how students develop the abilities needed by the labor market – helping them obtain, keep, or shift jobs [15], [16]. HEIs can also monitor and adjust their courses [17], enabling their students to achieve better jobs when compared to non-graduates [18]. Achieving better jobs is an appealing reason for starting a Higher Education Course [19], and one of the main goals of HEIs is to prepare their graduates to be workplace-ready, promoting employability [20], [21], [22], [23].

However, assessing the contribution of HEIs to employability is not a simple task [24]. Economy, localization, institutions, and many other factors have some impact on employability [25], [26]. This group of environmental factors that impact employability is called *context* [27]. Hence, employability can be assessed from different perspectives, such as individual, organization, institutional, or governmental [28].

Some employability perspectives lack deeper studies [8]. Therefore, we propose a novel approach to employability from the HEI's perspective. We created a framework composed of a novel employability definition and a model of this phenomenon called Higher Education Courses Employability (HECE). The framework helps HEI decision-makers to base their decisions on employability data. The framework also allows HEIs to assess employability from the HEI courses' perspective, evaluating the alumni's adherence to the labor market.

Software that implements the framework using real data was used, from the Brazilian context, to facilitate the evaluation of the framework. Brazil is an interesting case to be analyzed because evidence indicates a mismatch between Higher Education and the labor market: automation is expected to highly impact 60% of its workforce in the next decades [29], 40% of the graduated youth don't achieve jobs that require graduation [30], and more than 70% of recruiters have problems finding candidates with the minimum knowledge for jobs [31].

II. UNDERSTANDING EMPLOYABILITY MEASUREMENT

Before developing assessment tools, we need to understand employability and how to measure it. Some studies use the Operationalization process, which transforms social phenomena into something measurable, to define and measure employability [24], [32], [33]. However, other studies lack an explicit definition of employability [19], [34], [35], [36], [37], [38], adopting different methods to measure employability.

Employability can be analyzed from different perspectives [6], [28]. The first step of Operationalization is defining the employability concept. We define employability first because the measurement criteria further adopted rely on the employability definition [24].

Employability definition can differ, being open to interpretation [24], [27], [39]. Some studies measure employability from an individual perspective [8], [19], [24], [28], [35], [36], [37], [38], [40], [41], from a contextual perspective [6], [8], [24], [27], [42], [43] or even from an institutional/organizational perspective [8], [19], [28], [43]. This research will be focused on operationalizing the employability concept from an institutional perspective.

The next Operationalization steps analyze factors that impact employability. Many algorithms, models, or analyses can be used to determine the factors that impact employability [35], [36], [37]. There are differences in how the same factors impact employability, depending on the perspective chosen [44]. For example, age impacts the chances of someone finding a job [36], [37], [41]. However, when a group is analyzed, age provides another kind of impact on employability [6], [24], [27].

Among factors useful for different employability perspectives, we highlight age, gender, ethnicity, and social class [45], [46]. Factors such as academic performance and hard and soft skills are useful from the individual perspective [47]. In contrast, location, mobility, flexibility, area of study, sector of work, HEI type, and development opportunities can also be useful from a contextual/institutional/organizational perspective [27], [48]. Besides, all factors listed impact employability. However, their weights vary according to the perspective of employability analyzed.

We note that Higher Education influences the employability of individuals who have recently graduated and have little or no work experience [19], [35], [38], [41], [42], [49], [50]. Further professional experiences will increasingly outshine the graduation degree's influence on the individual's employability [51]. Therefore, the influence of Higher Education in the measurement of employability is related to the graduate's first job [41].

However, the HEIs provide opportunities for employability development and extracurricular experience [24], [35], [52], [53]. Teaching strategies and curriculum content significantly influence the construction of graduate employability [17], [34], [53], [54], [55].

The alumni's employment rate is a strong indicator of employability. We can use this indicator to build a ranking of HEIs [41] and to assess employability [27], [41], [42]. However, this practice commonly subverts the correct order of the Operationalization process, introducing bias into the measurement [24].

In the context of Higher Education, graduation will be an important factor for the employability of individuals. Higher Education courses open new job opportunities related to occupations that the course enables them to perform [50]. If such occupations are highly demanded of qualified professionals, the probability of graduates getting a job is higher [27].

The literature focuses on the analysis of individual employability. Some argue employability only applies to individuals, not institutions [24]. Therefore, we highlight the lack of studies analyzing macro-level employability. Rare exceptions explore other than individual employability [27], [43].

III. DEVELOPING THE HECE FRAMEWORK

We started developing our framework by expanding the concept of employability beyond the individual perspective. Therefore, we propose the framework HECE, a novel approach to measuring employability. Exploring the idea of course employability will allow HEIs to have tools built especially for them, developed by following the Operationalization methodology.

Operationalization is the process of turning a social phenomenon into something that can be measured in practice. This process is suitable for assessing a concept such as employability [24], [32], [33].

According to Harvey [24], the five steps to operationalize a phenomenon into something measurable are:

1) Define the theoretical concept to be adopted.
2) Break that concept into dimensions that cover the meaning of the concept.
3) Identify the set of indicators for each dimension and select indicators from each set.
4) Build collection instruments for each indicator.
5) Define the final set of indicators.

The Operationalization process produces a measurement encompassing several indicators to summarize the general concept but allows the researcher to decide the measurement scale for each indicator on employability [32].

A. OPERATIONALIZING THE HECE CONCEPT

In the first stage to operationalize HECE, the definition of the theoretical concept from the perspective of HEIs should be formalized. Therefore, we analyzed several employability definitions in the literature. Some employability definitions adopt an existing definition, and a few create new definitions from scratch or combine existing ones [24], [28].

Employability is among the most significant factors in choosing a graduate course at a specific HEI [56]. Although it was first used around 1955 [57], the scientific interest in employability grew around the 1990s, when it started guiding public policies [28].

De Grip et al. [58] state that employability is the junction between the ability and willingness of workers to remain attractive to the job market, reacting to and anticipating changes in tasks and the work environment. This definition

TABLE 1. Employability definitions and dimensions.

Author	Employability definition	Dimensions
[6]	The ability to obtain and retain suitable work	nature of employment, time after graduation, income, discipline
[24]	The individual's probability to exhibit attributes that employers anticipate will be necessary for the future effective functioning of their organization	teamwork, communication, risk-taking
[28]	The continuous realization, acquisition, or creation of work through the optimal use of skills	occupational expertise, anticipation, optimization, personal flexibility, corporate sense, balance

responsibilizes workers for their employability, despite some externalities. However, Boudreau et al. [59] consider employability as the attractiveness seen by firms in one individual, giving more importance to the employers and their requirements to fulfill job vacancies.

Despite some authors giving importance to HEI's influence on employability [24], there is a lack of studies that assess the perspective of HEIs' courses. Studies that consider the importance of Higher Education tend to minimize its influence on the individual's probability of obtaining and retaining a job. Our novel approach to employability focuses on HEI's undergraduate courses to bridge this gap.

According to Hillage and Pollard [6], employability is the capability of obtaining an initial job, retaining that job, and obtaining a new one if necessary. This concept of employability was adapted and expanded from focusing on a single individual to a set of individuals. This novel approach allows employability to be analyzed from the perspective of undergraduate courses. Thus, we define that HECE is the potential of the course to have graduates capable of obtaining a first qualified job, keeping in this job, or obtaining a new qualified job, if necessary. Our definition allows analyzing factors that affect employability for all undergraduates in a specific course and context, regardless of individual differences.

The second operationalization step is to break down the employability definition into independently assessable dimensions. The dimensions depend on the definition chosen for the concept [24]. Table 1 shows some examples.

We analyzed employability and found different dimensions encompassing undergraduates and alumni, course-related occupations, and other contextual factors influencing a HECE. These dimensions are:

- Obtain/Keep a job: the ability to obtain and keep a job considering occupations related to the course, which tend to be filled by current and future *alumni*.

TABLE 2. Chosen indicators description and collection instruments.

Dimension	Indicator	Description	Collection instrument
Obtain / Keep a job	Employment Balance	Evaluate whether occupations related to a course are losing or generating employment, allowing us to analyze the trend of future jobs.	Difference between hired and fired in occupations related to a course.
	Employment Balance Ranking	Evaluate the scenario concerning job creation of occupations related to a course against other occupations.	Position of occupations related to a course in the average employment balance ranking.
	Graduates vs. Employment Balance	The capability of the labor market to absorb workers looking for their first job after graduating.	The ratio between the graduates and jobs created in the occupations related to a course.
	Automation probability	The automation probability of occupations related to a course.	The average probability of occupations related to a course to lose job positions due to technological advances.
Job qualification	Education Level of Occupations	Indicates whether it is necessary to have a degree to perform the functions in the occupations related to a course.	Average education level of workers in occupations related to a course.
	Average Salary for Occupations	Evaluate the salary a graduate may receive in occupations related to a course.	The average salary among workers in occupations related to a course.
	Salary Comparison Between Graduates	Compare the scenario concerning the salary of occupations related to a course against other occupations.	Comparison of the average salary among workers in occupations related to a course with the average wage of all workers with a degree.
	Wage Premium	Evaluates how much more a graduate of the course may earn compared to non-graduates.	Comparison of the average salary among workers in occupations related to a course with the average wage of all workers who have only completed high school.

TABLE 2. *(Continued.)* **Chosen indicators description and collection instruments.**

Institutional difference	Teaching Staff Level	Evaluates the quality of the institution's teaching staff.	Comparison between the educational level of the teaching staff of an institution against other institutions that offer the same course.
	Course Rating	Indicates the quality of a course at an Institution according to official ratings.	Comparison between the rating of a course at an Institution and the rating of the same course offered in other institutions.
	Return on Investment	Indicates how much a worker will receive for investing in an undergraduate course.	Difference between course graduation cost and average Wage Premium for occupations related to a course.
	Payback Time	Indicates the average time a worker takes to pay for the investment in an undergraduate course.	Time for the difference between the course graduation cost and the average Wage Premium to become zero

- Job qualification: the attributes, specificities, and characteristics of the occupations related to the course, compared with other occupations.
- Institutional difference: the impact an institution has on all undergraduates' employability as a whole, compared with others that offer the same course.

The third step of Operationalization identifies and selects indicators for each dimension. We evaluated which indicators provide the best information for measuring each dimension. For the 'Obtain/Keep a job' dimension, we choose indicators that present the current state-of-art and future labor market trends. For the 'Job qualification' dimension, we choose indicators comparing occupations related to the undergraduate course with other occupations, showing the potential advantages of graduating on that specific course. For the Institutional difference dimension, we choose indicators that reflect the differences between graduating in different HEIs, including comparing similar courses in different institutions, allowing us to assess the institutional influence on employability.

The fourth step of Operationalization is the construction of the collection instruments. These instruments can be seen as a description, showing how to develop each indicator at a high level.
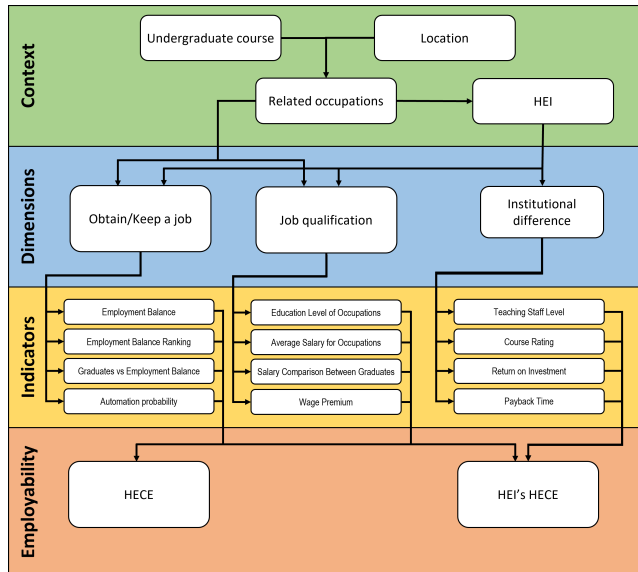
FIGURE 1. HECE model.

The fifth step of Operationalization aims to choose the indicators to compose the final set that will be used to assess employability. Therefore, we analyzed all indicators to select a set of indicators that are both important and fit into our research parameters – in terms of complexity to collect the measurement data. Table 2 presents the final set of 11 indicators.

B. BUILDING THE HECE MODEL

We used the definition, dimensions, and indicators to build a model representing the HECE. The model encompasses any undergraduate course since the indicators consider the context. The model accounts for environmental factors and changes in context that impact a course's employability. The model also considers the difference in impact on employability between HEIs that offer the same course. The context includes the current job market for graduates of these courses, accounting for regional variations such as urban mobility, primary education quality, employment opportunities, and other environmental factors [27].

The model considers two applicability scenarios to HECE. In the first scenario (HECE), the employability of an undergraduate course is independent of the institution. In the second (HEIs' HECE), the employability of a course is focused on a specific institution. The HECE has two dimensions: 'Obtain/Keep a job' and 'job qualification'. These two dimensions are sufficient to assess the HECE in a region. However, they only cover the first applicability scenario of HECE. The second applicability scenario requires the analysis of an additional dimension: 'institutional difference', which enables HEIs to evaluate their HECE. We summarize the HECE model and the applicability scenarios in Figure 1. Therefore, our model allows HECE comparison between HEIs.
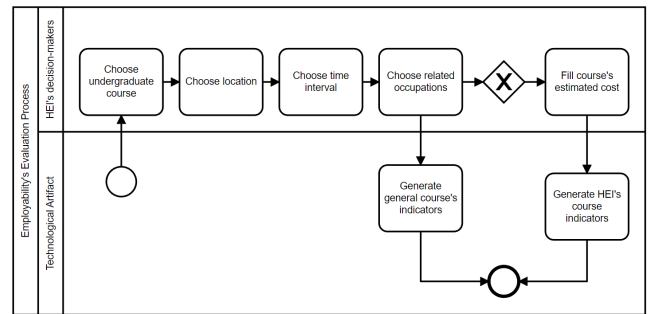

FIGURE 2. HECE assessment process.

IV. EVALUATING HECE

In this section, we evaluate the framework in the Brazilian context. Brazil presents challenges in both Higher Education and Employment. We highlight the gap between the qualifications of graduated job-seekers and the qualifications needed by the labor market, as 40% (525,000) of young Brazilians (22–25 years) with higher education did not have a qualified job [30]. Meanwhile, half of the Brazilian industries have problems with a lack of qualified labor [60]. Likewise, over 70% of job recruiters stated that candidates did not have the minimum knowledge for the vacancies offered [31].

The expected impact of automation is another challenge for the Brazilian youth. According to Lima et al. [29], 60% of the workforce in Brazil will be highly impacted by automation in the next decades. Besides, many job opportunities have been in highly automatable occupations.

The impacts of the COVID-19 pandemic also affected the HEIs. In 2021, an 18% budget cut in Higher Education affected 25% of undergraduate students [61], [62]. In 2020, underutilized workers grew by 23% – graduates had a 43% increase [63].

Therefore, the current scenario shows that Brazilian HEIs can benefit from the HECE framework. HECE framework provides indicators of how employable the HEIs' students are and stimulates reflections about improvements in curricula, course portfolios, teaching staff, and others. The HECE framework can reduce the gap between Higher Education and the labor market while improving the perception of the importance of Higher Education.

A. DEVELOPING THE SOFTWARE

The developed software uses Brazilian public data and the automation probability of each Brazilian occupation [29], being compliant with the HECE model (Figure 2). The software considers the possibility of choosing the context of the employability evaluation. For example, suppose an HEI evaluates the employability of the Civil Engineering course in region A. In that case, the decision-maker starts the process by choosing the Civil Engineering course from a list of courses. In the second step, the decision-maker selects region A. These steps enable the decision-maker to assess the employability of a course through indicators related to the job market (HECE applicability scenario). When evaluating
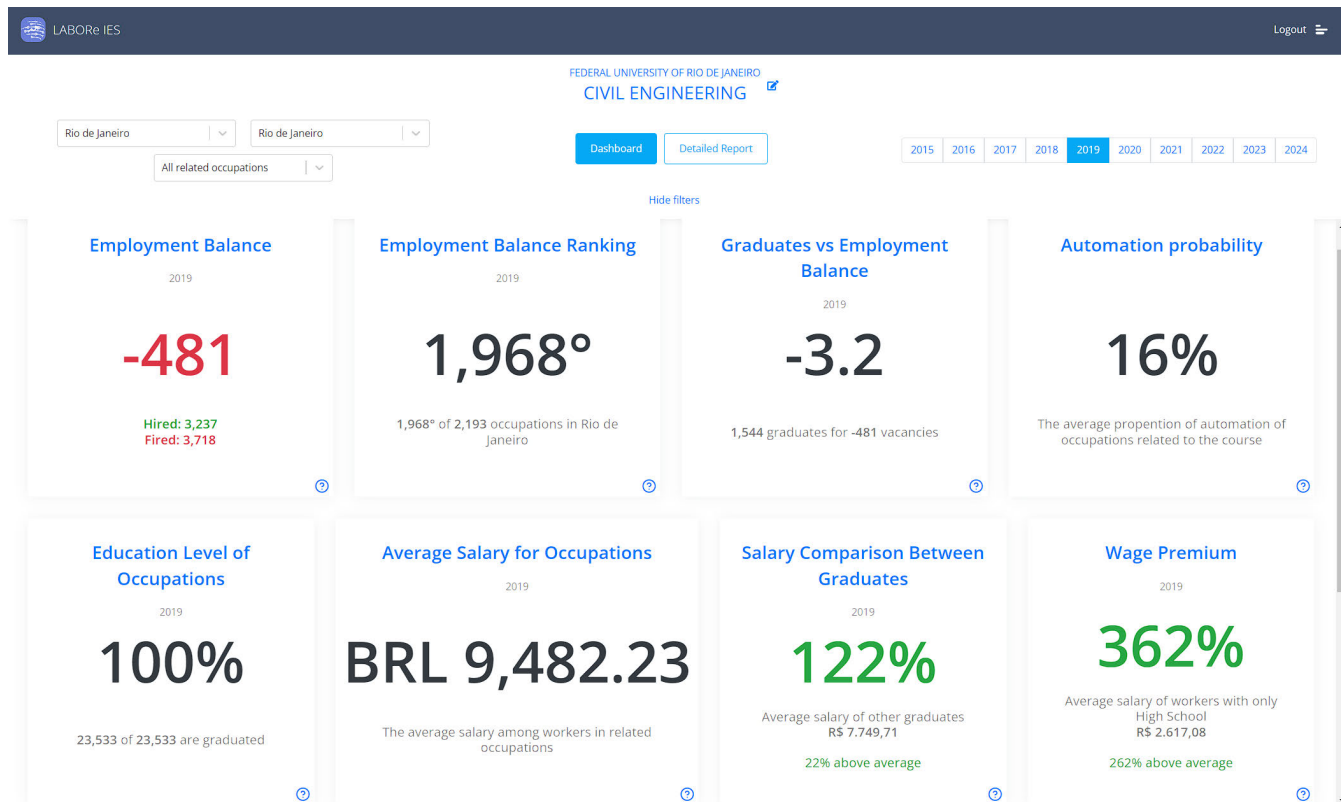
FIGURE 3. The software dashboard.

the employability of a course at a specific HEI (HEIs' HECE applicability scenario), the decision-maker must also perform the optional steps of choosing the HEI to evaluate and estimate the cost for an undergraduate student to complete the course. We highlight that the decision-maker can choose any HEI – i.e., the model allows evaluating competitor HEIs.

The software is a website that aggregates different Brazilian databases, allowing the HECE assessment for any Brazilian HEI. The databases used include all Brazilian HEIs, their courses, and the official government assessment of each course. Besides, the software includes occupation databases containing all registered (anonymized) workers' wages and all jobs movement in Brazil since 2015. The software also lists the automation probability of each Brazilian occupation.

The system presents a step-by-step wizard. Following the wizard, the decision-maker chooses the HEI and their graduation course, the localization, the time interval, and the course's related occupations. Next, the system aggregates the data in real-time to provide the HECE indicators according to the choices. The system presents the indicators in a dashboard, showing a high-level state-of-the-art of each indicator (Figure 3). The system also presents a Detailed Report, providing more information about each indicator and allowing a deeper understanding of HECE (Figure 4).

B. EVALUATING THE FRAMEWORK

We invited HEIs' decision-makers and experts from different Brazilian regions for an interview, in which they could use the software to evaluate the HECE framework. Our goal was to evaluate the HECE framework application in the Brazilian context. We performed each interview individually and remotely through videoconference. Table 3 shows the evaluators' information.

The evaluation interview had five stages: the project and framework presentation, the pre-evaluation interview, the use of the software, the response to the evaluation form, and the final remarks. In the first stage, the project and framework presentation, the interviewer briefed the evaluator about the interview process, the motivations to measure employability, and the framework. In the pre-evaluation interview stage, the interviewer asked some questions to the evaluator to obtain their view on the concept of employability and validate the concept defined in the framework. Then, the interviewer allows the evaluator to use the software that implements the framework for a short period (about 15 minutes). After the interview, the interviewer submitted an evaluation form to the evaluators. Then, the evaluators anonymously registered their perceptions regarding the usefulness and importance of the framework to aid decision-making. In the final remarks stage, the interviewer asked questions to capture any opinion missed on previous questions to understand the
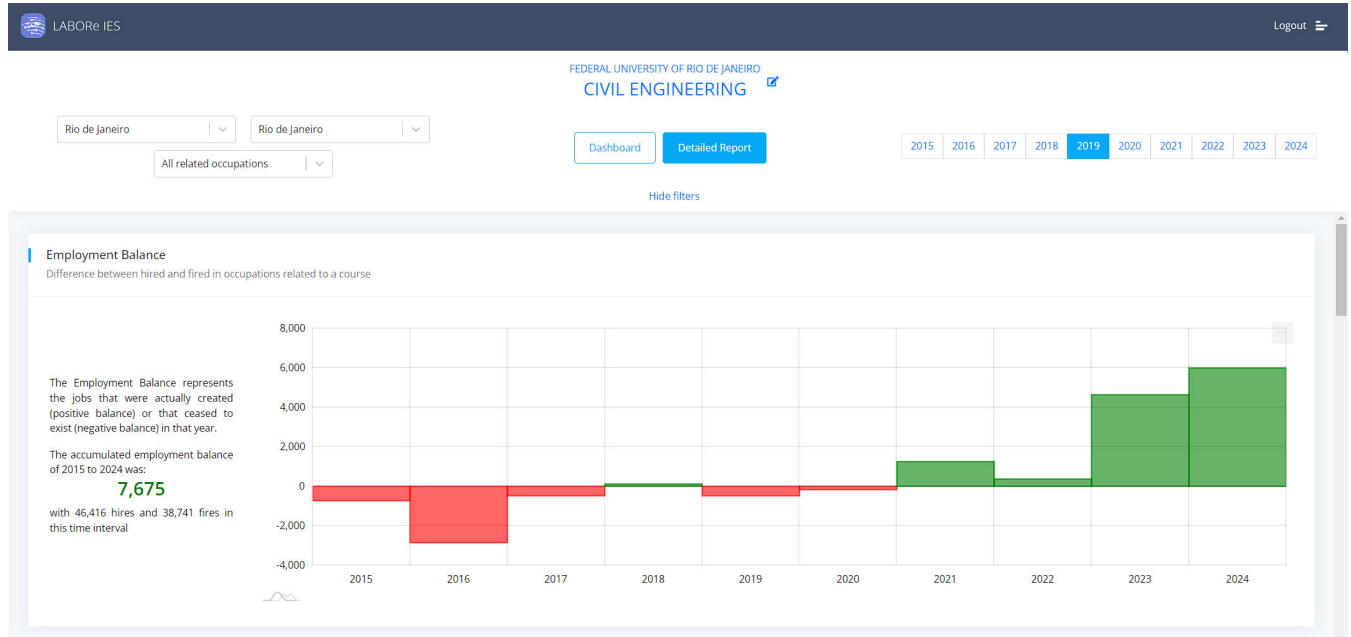
FIGURE 4. A detailed report.

general scenario of acceptance of the framework and to collect suggestions for improvements.

During the pre-evaluation interview stage, evaluators presented differing views on employability, including individual and institutional perspectives. Therefore, evaluators see the concept of employability from different perspectives. This difference validates the possibility of defining the employability of undergraduate courses.

The evaluation form was divided into three sections. The first section includes statements for the evaluators about the framework's usefulness. They responded with the level of agreement with each statement on the Likert scale [64], ranging from 'Strongly Disagree' (1) to 'Strongly Agree' (5). The second section assesses the degree of relevance of the indicators, showing how each indicator contributes to the employability of undergraduate courses according to the evaluators. The evaluators choose the importance of the indicators within a Likert scale, ranging from 'Very irrelevant' (1) to 'Very relevant' (5). The responses to each question are shown in Tables 4 and 5.

The third section evaluates their perception of the framework and its implementation through the software. These are open-ended questions. One evaluator notes that it 'facilitates decision-making regarding whether or not to offer a course'. Another evaluator considers the framework 'highly relevant for HEIs to evaluate courses in light of the labor market scenario'. Finally, another evaluator said the framework provides 'a comprehensive overview of the present and future of the field, thus aiding decision-making at the leadership and coordination level'. One evaluator also pointed out the innovative nature of the framework, stating, 'there are no such frameworks available to Brazilian HEIs'.

Concerning framework and software adoption, 9 of 11 (82%) evaluators said that the HEI they work on would adopt such a tool implementing the proposed framework to assess them in decision-making. When asked why he would not adopt the tool, the first evaluator answered that he observes management problems in his HEI, which denies the employability assessment. The second evaluator answered that his HEI already analyzes employability and changing their evaluation approach would be expensive.

The evaluators informed any useful information about employability is missing. In this question, 6 out of 11 (55%) responded that they did not miss any information. The other evaluators lacked comparative employability indicators between HEIs. They also reported missing indicators that show the differences between informal and formal labor markets and indicators that show the rate between *alumni* and the labor market size for a given set of occupations.

In the last question, the interviewer asked the evaluators to express opinions and provide suggestions about the framework and the software. EV 1 answered that despite being 'averse to charts and numbers', he was 'delighted with the tool and the framework'. EV 2 answered that the framework has 'extreme relevance' and the tool shows 'surprising results', feeling 'well impacted' with the results presented. EV 5 answered that the tool 'aggregates data capable of changing the direction the institution is taking' and the framework is 'extremely useful'. Finally, EV 7 answered that he was 'surprised by the framework', as it was 'interesting and innovative, allowing a reflection between courses offer and demand absorption' and with 'extremely relevant indicators'.

TABLE 3. Evaluators.

Evaluator	Formation	Function
EV 1	Ph.D. in Economics and MBA in HEIs' Management	HEI's dean
EV 2	Ph.D. in Computer Science	HEI's professor, Industry 4.0 specialist, and former coordinator of technical courses.
EV 3	Ph.D. in Education	HEI's course coordinator and HEI's evaluator for Brazillian's Ministry of Education.
EV 4	Ph.D. in Polymer Science and Technology	HEI's dean.
EV 5	Ph.D. in Computer Science	HEI's dean, HEI's evaluator for Brazillian's Ministry of Education, and former course coordinator.
EV 6	Master in Sociology	Employability data analysis specialist.
EV 7	Master in Social Sciences	Specialist in sociological concepts of employability.
EV 8	Ph.D. in Data Engineering and Ph.D. in Informatics and Society	HEI's education center coordinator.
EV 9	Master in Science and Technology Policy and Ph.D. in Production Engineering	Employability indicators specialist.
EV 10	Ph.D. in Business Administration, MBA in Machine Learning, and MBA in Higher Education Teaching	HEI's employability project manager.
EV 11	Master's in Applied Mathematics and Ph.D. in Philosophy of Science	HEI's science and culture coordinator and Brazilian politician.

TABLE 4. Usefulness and importance of the framework.

Affirmation	Degree of agreement (Min.: 1, Max.: 5)		
	Average	Median	Standard deviation
Regarding the IMPROVEMENT OF UNDERGRADUATE COURSES, the framework is useful to assist decision-makers in deciding on course improvements.	4,5	5	0,7
About OFFERING SPOTS FOR UNDERGRADUATE COURSES, the framework is useful to assist decision-makers in making decisions about how many spots to offer.	4,3	4	0,8

V. DISCUSSION

When analyzing the evaluators' responses, 7 out of 11 (64%) evaluators strongly agreed that the framework is useful to

TABLE 5. Relevance of the framework's indicators.

Indicators	Relevance degree (Min.: 1, Max.: 5)		
	Average	Median	Standard deviation
Employment Balance	4,7	5	0,6
Employment Balance Ranking	4,6	5	0,7
Graduates vs. Employment Balance	4,4	5	0,9
Automation probability	4,4	5	1,0
Education Level of Occupations	4,6	5	0,7
Average Salary for Occupations	4,9	5	0,3
Salary Comparison Between Graduates	4,6	5	0,5
Wage Premium	4,4	4	0,7
Teaching Staff Level	4,5	5	0,7
Course Rating	4,6	5	0,5
Return on Investment	4,4	4	0,7
Payback Time	4,1	4	1,1

assist decision-makers in making decisions about improvements to Higher Education courses. Regarding the usefulness of the framework concerning vacancies for undergraduate courses, 5 out of 11 (45%) evaluators strongly agreed that the framework is useful to assist decision-makers in making decisions about course vacancy offers.

Evaluation results evidence that the framework can assist in measuring the employability of undergraduate courses in Brazil, a country with continental dimensions and plural contexts. Therefore, we consider the application of the framework consistent in any context. The technological implementation of the framework has proven to be a good alternative to allow HEIs decision-makers to focus on information-rich analysis to base their decisions.

Although, the framework can receive some improvements. We highlight the lack of a measurable index through an automatic process. Further research is required to identify new indicators and weight factors influencing employability before developing an index based on the presented operationalization results. The index would help HEI decision-makers prioritize actions to enhance their HEI's course employability.

Another improvement point was identified in the framework during the interview process. Since undergraduate courses take years to be concluded, any decision using the framework will take a few years to produce the desired effect. These effects could be estimated using forecasting methods. We already implemented the first stage of the forecast using a mathematical optimization technique called least squares regression [65], which allows us to estimate future values for each indicator based on trends observed in historical data. We expect to further improve the forecast by adjusting the future values by considering changes in external factors.

VI. CONCLUSION

The 4th Industrial Revolution is expected to impact occupations more than the previous ones, with new technologies transforming virtually all professions, making some traditional professions disappear while new professions emerge [66]. The COVID-19 pandemic can intensify this transition, transforming the way companies, governments, and individuals work, bringing within two years changes expected for the medium/long term. COVID-19 also caused a reduction of investment in Higher Education by the government, while the population avoids investments in education that bring uncertain financial benefits.

Meanwhile, HEIs have no tools to evaluate their undergraduate courses in the face of the changing demands of the labor market, increasing the reported gap between the theory taught in HEIs and the practice performed on the job [67].

In this work, we propose a novel framework to measure employability from the perspective of HEIs, named HECE. We started with the goal of transforming the social phenomenon of employability into a set of measurable indicators. We use the Operationalization process to define the HECE concept and a model which composes the HECE framework. Then, we developed software that uses public data and data generated by related work to evaluate the validity and usefulness of the framework by decision-makers and employability experts.

The evaluation results show that the proposed framework can directly impact Higher Education. HECE has proven to be a powerful tool for decision-maker to base their decisions regarding course offerings and vacancies, helping change and adapt their courses' curricula.

Another research field involves the application of the methodology developed in this work to build similar frameworks for governments and organizations. We can also apply this methodology to build frameworks for different levels of education, such as technical and vocational education.

Finally, we highlight the importance of understanding which technical skills are required by an occupation to perform its activities. Further research to link occupations to undergraduate courses is important to improve the framework and automatically link courses to new occupations that can be created over the years. We can also link occupations with new undergraduate courses that can be created. The use of future estimations enables HEIs to anticipate problems and make new strategic decisions about the offer of courses and curricula proactively, aiming to form professionals prepared for the future.

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HERBERT SALAZAR DOS SANTOS received the B.S. degree in computer science and the M.Sc. degree in systems engineering and computing from Universidade Federal do Rio de Janeiro, in 2019 and 2021, respectively, where he is currently pursuing the D.Sc. degree in systems engineering and computing. His research interests include data science, work, and decision support systems.
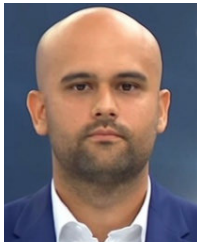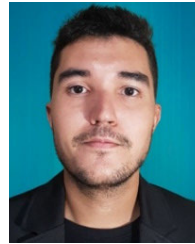
YURI OLIVEIRA DE LIMA received the B.S. degree in production engineering from Universidade do Estado do Rio de Janeiro, in 2013, and the M.Sc. degree in production engineering from the Universidade Federal do Rio de Janeiro, in 2016, where he is currently pursuing the D.Sc. degree in systems engineering and computing. In 2019, he has founded the LABORe consulting firm, which focused on providing insightful information about work to the government, companies, and unions to improve job creation in Brazil. Since 2016, he has been a founding Laboratório do Futuro (Future Laboratory) member with Universidade Federal do Rio de Janeiro. His research interests include work, technology assessment, and decision support systems.
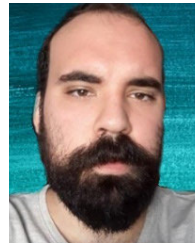
CARLOS EDUARDO BARBOSA received the B.S. degree in computer science and the M.Sc. and D.Sc. degrees in systems engineering and computing from Universidade Federal do Rio de Janeiro, in 2006, 2010, and 2018, respectively. Since 2010, he has been a Technologist with the Center for Naval Systems Analyses (Brazilian Navy), as a software development Technical Lead. Since 2016, he has been a founding Laboratório do Futuro (Future Laboratory) member with Universidade Federal do Rio de Janeiro. His research interests include futures research, knowledge management, decision support systems, and crowdsourcing.

ALAN DE OLIVEIRA LYRA received the B.S. degree in computer science and the M.Sc. degree in systems engineering and computing from Universidade Federal do Rio de Janeiro, in 2017 and 2021, respectively, where he is currently pursuing the D.Sc. degree in systems engineering and computing. His research interests include futures research and decision support systems.

MATHEUS MARGARIDO ARGÔLO received the B.Sc. degree in electronics and computer engineering from Universidade Federal do Rio de Janeiro, in 2021, where he is currently pursuing the M.Sc. degree in systems engineering and computing. His research interests include computer-supported cooperative work, knowledge management, work, and education.

JANO MOREIRA DE SOUZA (Member, IEEE) received the B.S. degree in mechanical engineering and the master's degree in computer science from Universidade Federal do Rio de Janeiro, in 1974 and 1978, respectively, and the Ph.D. degree in information systems from the University of East Anglia, in 1986. Since 1976, he has been researching and teaching computer science with Universidade Federal do Rio de Janeiro, focusing on the following subjects: databases, knowledge management, social networks, CSCW, autonomic computing, and negotiation support systems. He was on sabbatical leave with CERN from 1989 to 1993 (three months a year). Since 2016, he has been a Founding Member and a Leader of the Laboratório do Futuro (Future Laboratory) with Universidade Federal do Rio de Janeiro. His awards and honors include the IBM Faculty Award (in 2008 and 2007) and the Prêmio Bolsa Uol (in 2007 and 2006).

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