Online-Journals.org

iJEP International Journal of Engineering Pedagogy

iJEP | eISSN: 2192-4880 | Vol. 14 No. 7 (2024) | OPEN ACCESS

https://doi.org/10.3991/ijep.v14i7.48987

PAPER

Research Training: Unraveling the Research Methodological Design Challenge in Engineering Programs

Alexandre Almeida Del Savio[1], Katerina Galantini Velarde[2](✉), Ludy Cáceres Montero[1], Mónica Alejandra Vergara Olivera[1]

[1]Faculty of Engineering, Universidad de Lima, Lima, Peru

[2]Faculty of Architecture, Universidad de Lima, Lima, Peru

kgalanti@ulima.edu.pe

ABSTRACT

Research training stands out as a means to develop generic competencies, potentiate lifelong learning (LL), and integrate initiatives for compliance with the 17 Sustainable Development Goals (SDGs), contributing to the development of a resilient society. Therefore, the constant promotion of a research culture within higher education institutions is an essential task for reducing the gap between scientific productivity and industry challenges and proposing solutions to real-life challenges. One of the main stages involved in any research process is the proposition of a methodological design: a detailed plan conceived and later developed to answer the research questions. Nevertheless, within the engineering context, even though a wide range of methodological designs are considered, these are not always explicitly stated in research papers, so at the undergraduate level there is an absence of more precise guidelines that allow a more concise orientation. Consequently, at this level, a challenge in research training is perceived. This provided a motivation: the development of a framework for the actors involved in research training at the engineering undergraduate level so that they can easily define the methodological design. In this context, the present research proposes a framework organized upon the two main phases of every research process: design and execution. The framework is expected to promote the proper use of research methodology among engineering students. Furthermore, the methodological design from 140 selected civil engineering papers from seven different knowledge fields is analyzed. Results show that 94.29% of the papers did not explicitly present the methodological design. It was concluded that there is an absence of it within the engineering field. Thus, a methodological design framework proposal for engineering students was developed to overcome this situation.

KEYWORDS

methodological design, research competencies, research methodology, competency-based curriculum, research training, lifelong learning (LL), research-based learning (RBL), Sustainable Development Goals (SDGs)

Del Savio, A.A., Galantini Velarde, K., Cáceres Montero, L., Vergara Olivera, M.A. (2024). Research Training: Unraveling the Research Methodological Design Challenge in Engineering Programs. *International Journal of Engineering Pedagogy (iJEP)*, 14(7), pp. 30–53. https://doi.org/10.3991/ijep.v14i7.48987

Article submitted 2024-03-07. Revision uploaded 2024-07-24. Final acceptance 2024-07-24.

1 INTRODUCTION

Within the higher education context, research stands out as a means to potentiate lifelong learning (LL), which is the core of competency-based curricula. Indeed, research experiences facilitate the development and reinforcement of generic competencies [1], while providing students with tools to manage new information upon critical sense and based on intellectual curiosity [2], [3]. Therefore, research has been embedded throughout the curriculum as part of the training process within a variety of professional fields [4], [5], as it provides tools that allow graduates to stay competent and competitive while contributing to the development of society [6], [7]. In fact, research is associated with the integration of initiatives for compliance with the 17 Sustainable Development Goals (SDG), in line with the new paradigm based on social responsibility [8], which is why research training has become a fundamental piece within higher education.

Research is a set of systematic, critical, and empirical processes that are applied to the study of a problem: conducting observations, proposing questions, examining sources of information, planning research, using and developing tools to collect information, analyzing and interpreting data, suggesting solutions and explanations, and communicating results [4]. When approached from an international perspective, research allows universities to stay up-to-date upon their immersion in globalization and regionalization processes. International research networks, publications in high-impact indexed journals, and collaboration between international researchers, professors, and students are some examples of today's universities' focus to provide a wider visibility [9]. Certainly, increased attention has been given to the role of research within universities, as it is an essential indicator within higher education world rankings [10]. Therefore, research training becomes a key piece for the promotion of technological development and innovation within universities.

In this context, there is a need for articulating efforts between university and industry. This synergy plays a fundamental role for the advances in knowledge and the contribution to the consolidation of a resilient society through the development of innovative research that provides responsible solutions to the challenges of the environment [11]. In fact, in industrialized countries, knowledge is the most relevant factor in the production of new goods and services [12]. This has transformed the knowledge creation and transfer activities into essential factors for ensuring a balance between economic growth, environmental care, and social well-being among nations [13]. Higher education institutions have the potential to impact society, industries, and markets, transferring their scientific-technological advances and increasing productivity based on innovation [14]. Thus, research training is a fundamental pillar for reducing the gap between scientific productivity and the challenges of the industry [15]. Often, research training is applied within an environment of research culture, a context of interpersonal collaboration and encouragement where colleagues share affinity about the value of research [16]. In fact, research culture encompasses research experiences that prepare students for their professional lives [3].

Scientific productivity may be defined as the number of research papers a scientist publishes in a certain time, the impact factor of the journals where they are published, and the number of citations of each paper [17]. Scientific productivity has annually increased worldwide by 4% since 2009 [18]. In the case of Latin America, this number reaches 3% between 2016 and 2020 [19]. The increase in scientific productivity worldwide is relative to the graduate population, which, compared to 2000, has experienced considerable growth in countries such as China (589%), Turkey (236%), Taiwan (128%), and Germany (121%). Similarly, countries such as Canada, Mexico, South Korea, and the United States have experienced 50% growth [20].

Nevertheless, research experiences are also becoming progressively incorporated into undergraduate programs [4], [21], [22], [23], [24], [25] through research training, since undergraduate students may also offer intellectual or creative contribution to the discipline [26]. In fact, students face real-life challenges and propose solutions within the context of their profession [27], [28]. This promotes high-impact experiential learning [29] leading to a process of shared knowledge building [30]. At this level, students are still active subjects in training, while the professors provide guidance as part of their teaching roles [31].

As for the case of engineering programs, graduates are expected to master certain theoretical and practical knowledge, as well as deploy generic competencies, such as communication, working with multidisciplinary teams, and problem solving [32], [33]. These competencies can be developed precisely through the implementation of research experiences that allow research training. Research-based learning (RBL) appears as a learning methodology in which students become active inquirers, sharing experiences with staff, researchers, and professors through the application of strategies that link research with teaching [34]. RBL supports the development and reinforcement of generic competencies in students [1].

Every research experience should address the two main phases of every research process: design and execution. These phases imply carrying out activities such as conducting observations, proposing questions, formulating a problem, examining literature, planning research, developing and applying tools for collecting data, analyzing and interpreting information, suggesting solutions, and communicating results [4]. Among these, proposing a proper methodological design is considered an important aim among higher education students, as in the professional environment this is translated to problem-solving skills through previously established tasks [35].

In fact, a clear, detailed, and consistent methodological design allows properly executing the research. Methodological design is the plan conceived and later developed to answer the research questions [36]. If the design is well conceived, the final product of the research will have a greater chance of being valid [37], as the development is properly defined. Furthermore, if clearly stated, it is possible to be applied in similar and further studies. A proper methodological design is required in order to increase the level of knowledge from previous results obtained by others, which includes identifying a problem and solution validation, as this will ensure replicability [38]. Moreover, methodological analysis can support research-training activities by identifying areas of improvement in the choice and use of methodologies [39].

Methodological design may be defined as a process that details the steps to be followed in order to conduct a research investigation [40]. It includes the approach, the purpose, and the design, which are expected to be found explicitly in reports. Methodological design should also explain why the researcher chose the issue; why the study was designed by the researcher in that way; why alternatives were rejected; what were the questions the researcher was asking; and how the researcher ensured that confidence could be felt in the data gathered and in their analysis of those data [41].

Within the engineering context, even though researchers consider a wide range of methodological designs, most of them are neither explicitly nor properly reported [39]. In fact, methodological design was studied within a group of engineering research papers to validate this affirmation. The lack of explicit methodological design within these papers provided a motivation: a framework proposal for engineering researchers so that they can easily define the methodological design. This framework is organized upon the two main phases of every research process: design and execution.

To achieve this goal, first, the terminology regarding the elements of methodological design is introduced. The key elements that should be present in every methodological design within engineering research projects are identified. Second, the data regarding the analyzed engineering research papers from the selected databases are presented and classified. Thirdly, a framework is suggested as a recommendation on how to propose a research methodological design within the engineering field. The framework is expected to promote the proper use of research methodology among engineering students. Below, the following sections are developed: systematic review, methods, results and discussion, and conclusions.

2 SYSTEMATIC REVIEW

For the use and development of the tools to gather data, every research project relies on a methodological design. Literature defines three pillars of methodological design: approach, purpose, and design, as illustrated in Figure 1. These determine activities and procedures that must be applied to answer the research questions [42]. In this section, the three pillars of methodological design are addressed.

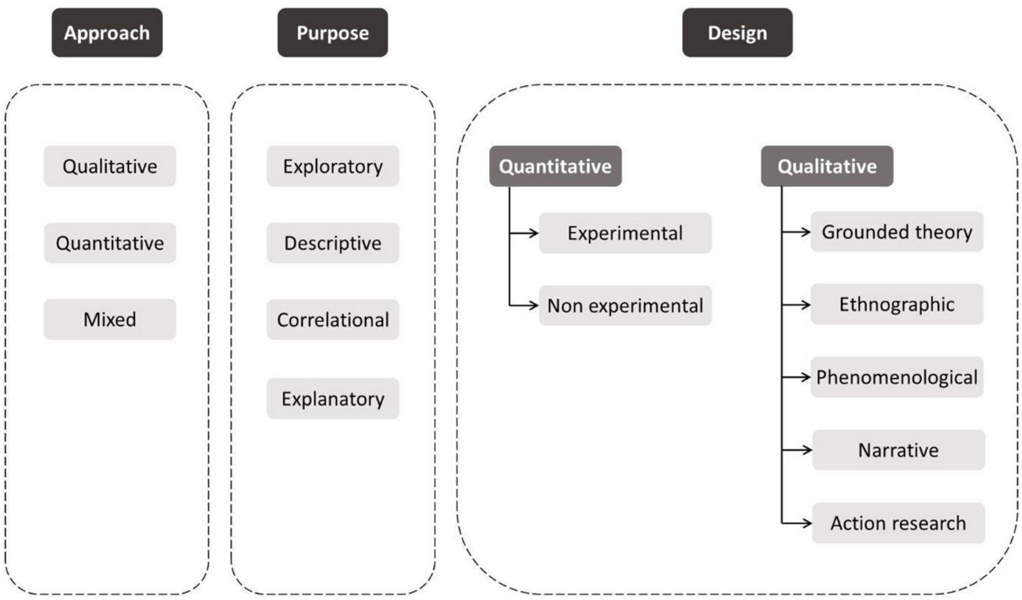

Fig. 1. Pillars of a methodological design: approach, purpose, and design

2.1 Approach

The approach is the route for knowledge construction, so it answers to the nature of the questions that are formulated from the proposed research problem.

The approach must meet a set of postulates, rules, and standards for the study and the solution proposal of the research question. The approach itself will then depend on the object of study and the hypotheses to be tested [43]. The approach may be quantitative, qualitative, or mixed. In engineering, the three of them are supported by mathematics and statistics with the aim of detecting patterns that may allow drawing conclusions about the phenomena that are representative.

Quantitative approach: On one hand, in the quantitative approach, numerical measurements and statistical analysis are used as a basis to prove hypotheses and to solve the research question based on factual data. To achieve this, quantitative research implies the possibility to define and isolate study variables from which data is collected [44]. Based on positivism ideas, this approach relies on the premise that every research problem, even within the context of social sciences, must be measurable, as in natural sciences, looking for objectivity [37]. In fact, the word "quantitative" refers to numerical counting and mathematical methods [45]. For this approach, the literature review is the guide, as it permits establishing the problem, defining the theory, formulating the hypothesis, proposing a research methodological design, and the other processes involved in the research process.

Thus, the quantitative approach is deductive, from general to particular, and starts from a delimited idea based on previous research, which is derived to research questions and objectives [46]. It implies a sequential and probationary workflow, reviewing literature to establish relationships between variables. A plan, the methodological design, is proposed to test these relationships upon measurements in a given context. Then, data is collected from a variety of standardized sources, such as surveys or experimentation. Statistical methods are used to process and analyze this data so that conclusions can be drawn based on the detected trends [47], [48]. Within the engineering field, quantitative research is conducted to identify how outcomes, such as mechanical failure, vary by manipulating a group of indicators: the variables [46].

Qualitative approach: On the other hand, in the qualitative approach, data collection and analysis are carried out to refine the research question or reveal new ones. The word "qualitative" refers to the nature, characteristics, and properties of phenomena [45]. This approach is based on the idea that, in addition to the description and measurement of variables, subjective meanings, perspectives, experiences, and understanding of the context in which the research problem occurs must be considered. Hence, it admits subjectivity. For this approach, the literature review provides a direction, but what mainly points to the route are the events during the study and the learning obtained from the participants, which allows adjusting progressively the research questions [37].

Therefore, this approach does not use numerical measurement. In fact, it is considered to be inductive, from the particular to the general, and flexible, as it is substantiated on its own, and questions and hypotheses are formulated before, during, or after the data collection and analysis. These activities serve, first, to discover the most important research questions and then to adjust and answer them within the interpretation process. Consequently, the research process is dynamic, as the sequence is not always the same, depending on the specific study [49]. Within the engineering field, qualitative research may be used to study the instructional interventions [50].

Mixed-method approach: Finally, the mixed-method research relies on both the quantitative and qualitative approaches. Therefore, quantitative and qualitative data are collected concurrently or sequentially within a single study, and they are integrated at some stages within the process of research. Lately, studies rely, every time more often, on this approach, as it combines the virtues of quantitative and qualitative research [45].

2.2 Purpose

The purpose, sometimes identified as the scope, determines the research strategy to be used within the investigative process for the data collection. According to literature, there are four major purposes: exploratory, descriptive, correlational, and explanatory [37]. The purpose should not be considered as a type of research since they constitute a continuum of "causality" that a study may have.

Exploratory: Exploratory research is used when the objective is to examine a novel topic. Exploratory studies allow obtaining information about the possibility of carrying out more complete research regarding a particular context, investigating new problems, identifying variables, establishing priorities for future research, or suggesting affirmations. They imply becoming familiar with relatively unknown phenomena so that concepts, the variables, and potential relations between them may be identified [51].

Therefore, in the case of engineering, it is expected that this type of research will allow researchers, professors, and students to arouse interest in further research on a specific topic, as what is already known about a study object is inquired about. Some further examples are: development of a methodology for the detection of cracks in concrete structures through ultrasound and artificial intelligence; study of professors' perceptions upon undergraduate research within a civil engineering program; or implementation of an atmospheric model to determine rainfall on a specific terrain.

Descriptive: Descriptive research is used to search for properties, profiles, and characteristics of the studied phenomena. It looks for tendencies in a universe, so it implies the measurement of one or more qualitative and quantitative attributes through various tools, from observation to checking already known patterns [37]. Thus, in this kind of study, the researcher must be able to define what will be measured, the variables, and on what or who the data will be collected. Each variable is measured independently from the others with the purpose of elaborating a precise description. Descriptive research relies on descriptive statistics for analysis [52].

Within engineering, descriptive research seeks to bring researchers, professors, and students closer to applied studies so that they can conclude from what is found by variables whose behavior has already been studied by literature. An example may be the creation of a new dataset of paved and unpaved roads in high-resolution aerial imagery, the development of a numerical simulation of extended plate steel connections subjected to bending and axial forces, or the thermo-mechanical characterization of embankment material incorporating blast furnace slag.

Correlational: Correlational research aims to determine the existing or none relationship between two or more variables and the degree or intensity of this interrelation. This relationship may be positive or negative. Thus, these studies associate variables with the purpose of predicting patterns, so each of them must be first measured independently. The main utility of correlational studies is to find out how a variable will act when knowing the behavior of other linked variables. Correlational research relies on inferential statistics for analysis [53].

In engineering, this could be exemplified with the relationship between the type of cement in a concrete mixture and its mechanical properties. Some examples are: addition of polypropylene and steel fibers to determine the variation in concrete's resistance to traction forces; analysis of the structural performance of a reinforced concrete frame with an SLB seismic energy dissipator subjected to a monotonic lateral load; or study of the variation in seismic response of embankments reinforced with polypropylene fibers founded on soft soils.

Explanatory: Explanatory research, also known as causal research, looks for the causes of the events or phenomena that are studied. Thus, its purpose is to find an explanation for which it establishes the nature of the relationship between the phenomena, the dependent variable, and one or more independent variables. It implies the control of the variables, from the theoretical framework to the final conclusions of the work. However, it is intended that this control represents the natural environment in which phenomena occur. These studies are more structured and imply the above-mentioned purposes since they rely on exploration, description, and correlation processes. Therefore, they rely on inferential statistics for analysis [51].

In engineering, this may be a study about why the implementation of a new management methodology could benefit a construction project or an investigation to explain the reasons for a professional competencies' gap among a group of engineering students and the labor market.

2.3 Design

The design, also identified as research strategy, is the proposed plan to gather the data for the research [54]. It implies procedures and activities to answer the research questions. The design answers to the research approach. Therefore, the existing designs are not the same for quantitative or qualitative research [37]. On one hand, quantitative research may have an experimental or non-experimental design [55].

Experimental design: Experimental studies are those where one or more independent variables (causes) are intentionally manipulated to analyze the consequences of such manipulation on one or more dependent variables (effects). This manipulation occurs within a controlled environment [56]. According to this environment, experimental studies may be laboratory or field experiments. In laboratory studies, the effect of all or nearly all influential independent variables, not relevant to the research problem, is controlled. Furthermore, laboratory studies are often experiments, and their advantages involve control in the design, setting, researcher, participants, and measurement [57]. In field studies, the experiment takes place in a real situation, so the researcher can only manipulate some of the variables [37]. Additionally, field studies allow researchers to understand the problems encountered in practice and come up with solutions that can be turned into action [58].

Furthermore, the experimental design involves working with two groups: experimental and control. The first one receives the stimuli, and the second one does not, in order to compare the obtained results [59]. It may be characterized as pre-experimental, true experiment, or quasi-experimental. Pre-experimental is a single-group design with minimal degree of control, as the group is kept under observation after implementing factors of cause and effect. True experimental is a double-group design with random distribution and manipulation of the independent variable to compare the groups and establish a cause-effect relationship. Quasi-experimental is almost like the true experimental, but the group participants are not randomly assigned [60], [61].

Therefore, a pre-experimental design may study the practical implementation of real pre-stressed two-layer reinforced concrete beams using high-strength steel fibered concrete [62]. A true experiment design may involve analyzing the effect of adding microfibers randomly to concrete samples to test the variations on the mechanical properties of the specimens. A quasi-experimental design may compare the effects produced on learning between two groups by the introduction or not of new software to teach Building Information Modeling (BIM) to students.

Non-experimental design: Non-experimental studies are carried out without deliberate variable manipulation, so phenomena are only observed in their natural environment for analysis. A non-experimental design can be cross-sectional or transversal. In cross-sectional studies, data are collected at a single point in time; in transversal or longitudinal studies, data are collected at different points in time to make inferences about the evolution of the research problem and its causes and effects [63], [64], [65]. For example, a cross-sectional study may determine the principal research topics in environmental science and engineering during a particular year [66], and a transversal study may determine a software process improvement effort over time and the factors associated with this process [67].

On the other hand, qualitative research may have a grounded theory, ethnographic, phenomenological, narrative, or action research design [55]. However, it should be noted that every qualitative research is unique, as each study depends on the conditions of each particular context [68].

Grounded theory: Grounded theory studies are focused on developing an explanation about a phenomenon that is applied to a specific context and from the perspective of various participants. For this explanation, theoretical variables or categories are defined from the data, which are collected until saturation. Data saturation describes a situation where data tends to repeat or where data no longer offers new directions to raise original research questions. Therefore, this type of study is both a design and a product [44]. In engineering, this may be the development of a theory regarding the user's perspective about the application of a new material in buildings.

Ethnographic research: Ethnographic studies describe what people from a particular context usually do, as well as the meanings that they give to that behavior. Data are gathered mainly through direct observation. In fact, participants in "action" are analyzed, and results are presented to understand them and their associated practices. Thus, this design seeks to interpret ideas, beliefs, meanings, and practices present in a specific social system. In engineering, ethnographic research is used every day in the practical development of technology, specifically in the context of user experience design [69].

Phenomenological research: Phenomenological studies describe phenomena as consciously experienced by people in the real world to uncover the common elements of such experiences. Similarly, narrative research focuses on understanding the succession of facts, situations, phenomena, processes, and events where thoughts, feelings, emotions, and interactions are involved through the experiences recounted by those who experienced them. Stories are reconstructed, resulting in categories that are built together to assemble an overarching story. Consequently, data are gathered through direct observation, interviews, and focus groups. In engineering, phenomenological research may be applied to examine professional conduct from an ethics perspective [70].

Action research: Action research studies seek to comprehend and solve problems from a particular community in a specific context. They are based on generating a change, which needs to be fully incorporated into the research process. The investigation takes place simultaneously with the intervention, so that knowledge is generated and applied at the same time. Data are collected from the members of the universe from which the study focuses, and participants can serve as co-researchers since they need to constantly interact with the data. In engineering, for example, within the education field, action research may involve professors making systematic and documented improvements within the classroom environment [46].

3 METHODS

In this section, the context of the present study is described. The data collection and data analysis techniques and tools are also addressed.

3.1 Context

The context of the present study is the research process. According to [71], there are multiple tasks and descriptions referred to by literature that should be developed along this process. These tasks, although not always linear, are sequential, so they may also be understood as phases. In fact, every research proposal should start with a purpose, which encompasses questions to be answered, objectives to reach this goal, a methodological design describing how, and the data will be gathered and analyzed. During this phase, practical aspects should also be considered, such as the resources' availability and the proposal's feasibility. Later, the methodological design is executed so that the research questions may be answered and the objectives achieved [71].

Thus, three subprocesses may be identified: one conceptual design, which includes the research challenge that needs to be addressed; two methodological design, the detailed strategy description to solve the research challenge; and three development, the implementation and attainment of the proposed strategy. Figure 2 shows a schematic diagram outlining the general guidelines for designing and developing a research process.

Furthermore, these three subprocesses respond to the R+D+i+e (Research, Design, Innovation, and Entrepreneurship) system, which has become indispensable for designing effective higher education and public policies [72]. According to R+D+i+e, systems at the university level revolve around four central activities: basic research, applied research, knowledge protection, and technological transfer. Depending on the nature and type of knowledge generated, its protection forms and transfer to society may vary. For example, knowledge may be protected through scientific publication or patent, while technological transfer may occur through startups or the sale of technologies.

Within this study, the methodological design, which is part of the design phase, as depicted in Figure 2, is analyzed because it has been noticed that researchers within the engineering field do not explicitly state this in papers.

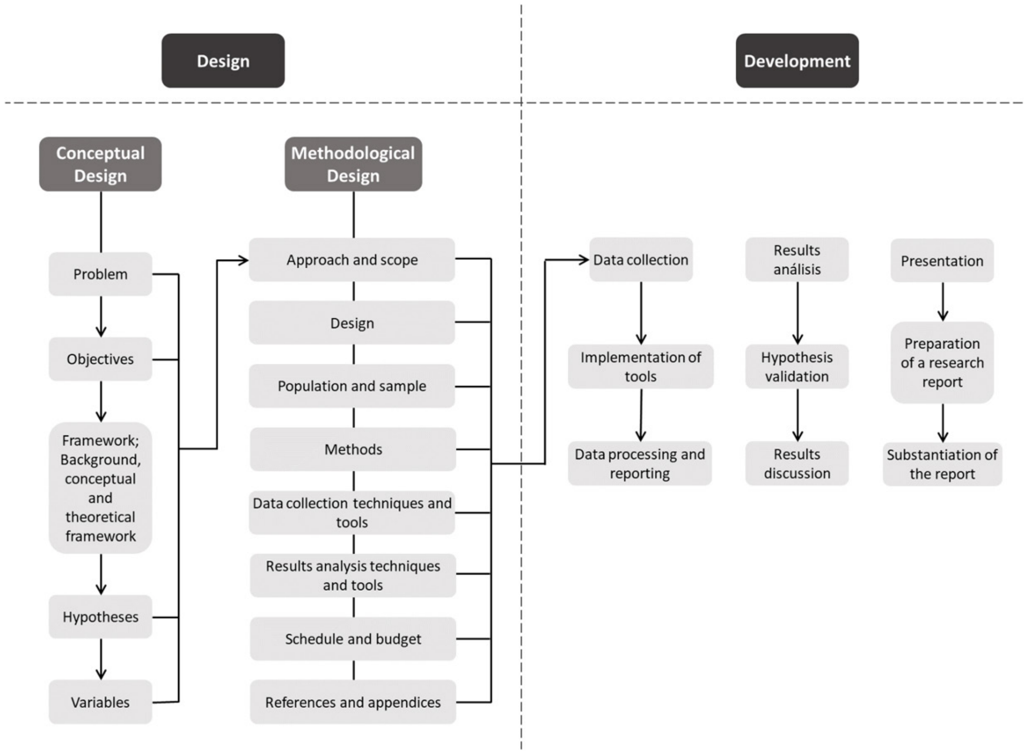

Fig. 2. General guidelines for designing and developing a research process

3.2 Data collection and validity of results

For this study, 140 research papers published in scientific journals, indexed on the Scopus database. The inclusion criteria for the selected papers were: publication date and study area; quartile (Q); and H-index from the journal in which it was published. These criteria were validated in SCImago Journal & Country Rank (SJR). SJR calculates journal indicators, which are developed from the information contained in the Scopus database. It is a public online portal that classifies journals and countries according to scientific indicators that measure their impact [73].

The Q reflects the demand for the journal by the scientific community, as these are ranked from the highest impact factor to the lowest and then divided [74]. The H-index is the number of the sequence of papers that some citations are equal to or are greater than the rank of the sequence. This indicator measures the productivity and citation impact of the publications [75].

About the publication date, papers published in engineering journals from 2016 to 2022 were considered. Editorials, introductions to special issues, letters to the editor, columns, and short papers were not included. About the study area, seven knowledge fields within civil engineering were defined: structures, transport and geotechnics, engineering sciences, project management, construction, hydraulics, and engineering education. The sample implied analyzing 20 research papers for each of the defined areas. Furthermore, only journals from Q1 or Q2 with H-index no lower than 25 were studied. Q rank the journals from the highest to the lowest according to their impact factor, so this implies that only the top 25% in the list (Q1) and the 25 to 50% (Q2) journal groups were examined.

Thus, the Scopus database was used for the journals' search. Additionally, Web of Science (WoS), a collection of bibliographic reference databases and information analysis resources, was also revised to ensure the selected journals were also indexed by it. To filter the information from the research papers obtained in the journals, keywords were used as search criteria in the Scopus database, as seen in Table 1. From the obtained universe, 140 research papers were taken, chosen randomly per knowledge area in the years considered (2016–2022) within the civil engineering field.

Table 1. Selected keywords used as search criteria in the Scopus database

Knowledge Field	Keywords	Results (N)	Representativeness (%)
Structures	structures, structural design, civil engineering, engineering	818	2.44%
Transport and geotechnics	transportation, civil engineering	1,513	1.32%
	geotechnics	1,065	1.88%
Engineering sciences	civil engineering, sciences	1,365	1.47%
Project management	project management, engineering	11,358	0.18%
Construction	construction, construction industry, civil engineering	1,732	1.15%
Hydraulics	hydraulics, engineering	6,850	0.29%
Engineering education	civil engineering, education	5,462	0.37%

For this analysis, civil engineering was chosen, as it is one of the most traditional fields of engineering and among those with the highest volume of papers in journals indexed in the Scopus database. Moreover, civil engineering plays a pivotal role in shaping economic models worldwide, given its involvement in industries such as energy and infrastructure, among others. While the focus of this analysis lies on civil engineering research proposals, this study aims to be a reference case that can be replicated across various engineering disciplines. The objective is to test the hypothesis proposed herein: the recurrent absence of an explicit methodological design in engineering papers.

Table 2 shows the summary of the papers indexed in the Scopus database from 2016 to 2022, within the fields of civil and structural engineering, amounting to 624,528. Consequently, a sample size of 140 articles was determined for this study, with a margin of error of 8.3% and a confidence interval of 95%.

Table 2. Papers in civil and structural engineering from the Scopus database

Year	Total per Year
2016	60,445
2018	60,311
2018	68,581
2019	81,316
2020	76,939
2021	87,253
2022	92,233

Source: SCImago Journal & Country Rank (SJR).

From the selected papers, a co-occurrence analysis was made using the bibliometric software VOS viewer. Links between the key words of the analyzed papers were generated considering the number of times they appeared in the group of papers [76], as shown in Figure 3. This pattern allowed the identification of the most used terms in the selected papers related to civil engineering.

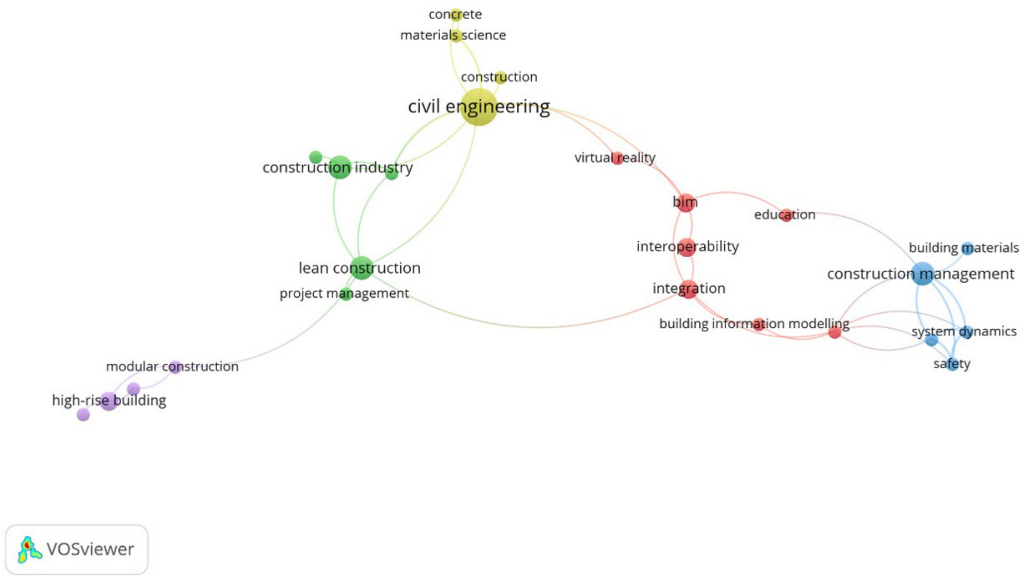

Fig. 3. Co-occurrence of keywords in analyzed papers

The study was developed in three stages: a systematic review was carried out to determine the pillars of methodological design; a documental analysis about engineering research papers within its knowledge fields was developed; and a framework was proposed, unraveling the worldwide methodological statements defined by literature and articulating them to the engineering field. This framework is meant as a tool for the orientation of engineering students and for the proposal of their own methodological designs within the context of their research projects.

3.3 Data analysis

For the analysis of the collected data, the three pillars of a methodological design were considered: approach, purpose, and design, as depicted in Figure 1. These were identified within the research papers from the sample. This information was properly processed using Microsoft Excel. The values and evidence recorded were stored for analysis [37].

As for the analysis, a workflow was established, as shown in Figure 4. First, the general data of each paper was recorded: title, authors, and year of publication. Later, the information regarding the journal in which each paper was published was checked in SJR: journal's name, Q, H-index, and impact factor. Finally, it was determined if each of the pillars of methodological design appeared in an explicit or an implicit way throughout the paper. For the ones that got this information explicit, the data was transcribed. For the ones that did not, it was deducted from the data found throughout the paper. The classification was based on analyzing the entire paper, not only certain parts, such as the abstract, keywords, or a specific section. The decisions about the missing pillars were made based on the discussions and final agreement among the researchers.

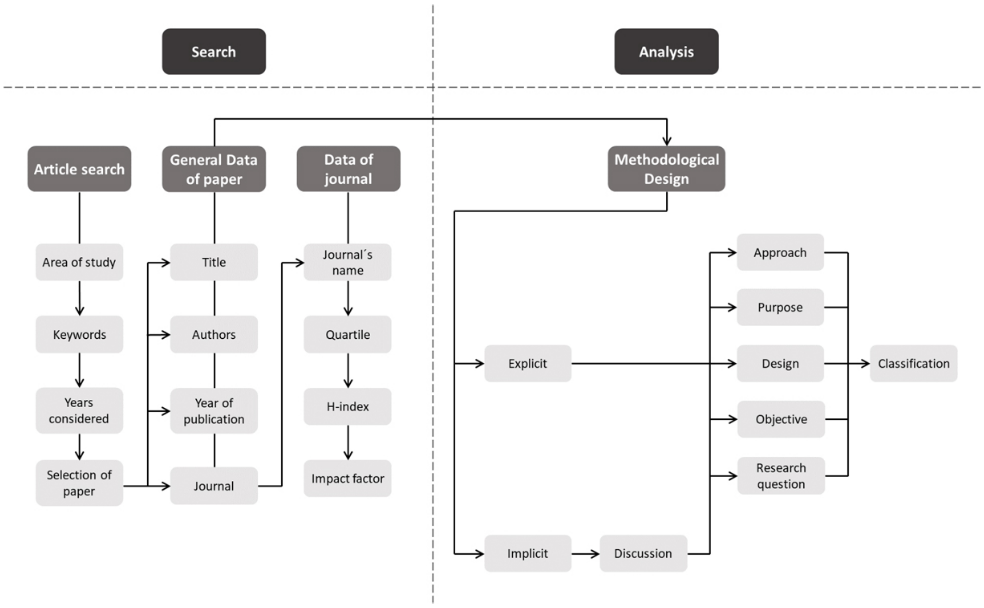

Fig. 4. Workflow for the collected data and its analysis

Additionally, data collection and data analysis strategies were also studied. Even though they are in principle independent of each other, some research paradigms tend to use certain methods for data collection and analysis [37]. Data collection lists the techniques that have been used in the research: laboratory tests, field tests, observation, questionnaires, interviews, and software data logs [39]. Data analysis details the way in which the collected data has been processed and analyzed.

4 RESULTS AND DISCUSSION

The following section is organized into two subsections. The first one describes and discusses the results from the research papers' analysis. The second section details the proposed framework on how to propose a research methodological design within the engineering field.

4.1 Research papers' analysis

In this section, the results from the analysis of the 140 research papers are presented. First, the results regarding the three pillars of a methodological design are addressed. Later, this data is segmented by years and knowledge fields. Finally, the analysis deepens on the specific approaches, purposes, and designs.

Figure 5 reveals the results from the analysis of the pillars of methodological design: approach, purpose, and design. Following the workflow designed for this research, it was determined if they appeared in an explicit or an implicit way throughout the paper. About the approach, in 78.57% of the analyzed research papers, it must be inferred by the readers, as only 21.43% explicitly address it. Moreover, regarding the purpose, 64.29% do not declare it explicitly, and only 35.71% do. Similarly, 67.86% do not report the design throughout the paper, and only 32.14% do. This absence may be related to the fact that research methods are so familiar to researchers with backgrounds from engineering or natural sciences [77].

Moreover, after identifying the pillars of methodological design in the 140 analyzed research papers, only eight presented the three of them, which represents

5.71% of the sample. Furthermore, 47 papers, which represents 33.57% of the sample, do not explicitly state the objectives of the present research. These results support the findings from the studies conducted by [39].

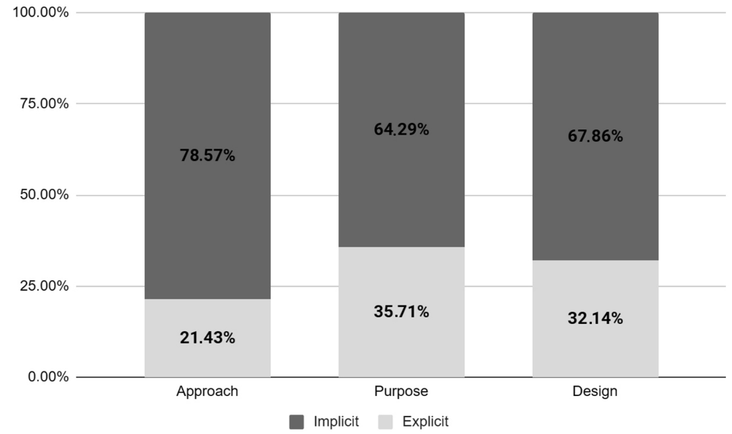

Fig. 5. General report of the pillars of methodological design—approach, purpose, and design—within the analyzed sample

Furthermore, when analyzing this data through the years, it can be observed that there is a growth upon the report of the pillars of methodological design, as shown on Figure 6. In fact, in 2016, only three papers report the design, one report the purpose, and none reports the approach. However, in 2021, 15 papers indicate the design; 16 papers, the purpose; and 10 papers, the approach. This tendency may be understood by considering the importance of scientific productivity among researchers [78]. A researcher's scientific productivity may increase as a result of an increase in the citations, which, at the same time, has a greater probability of growing if the study has replicability [79].

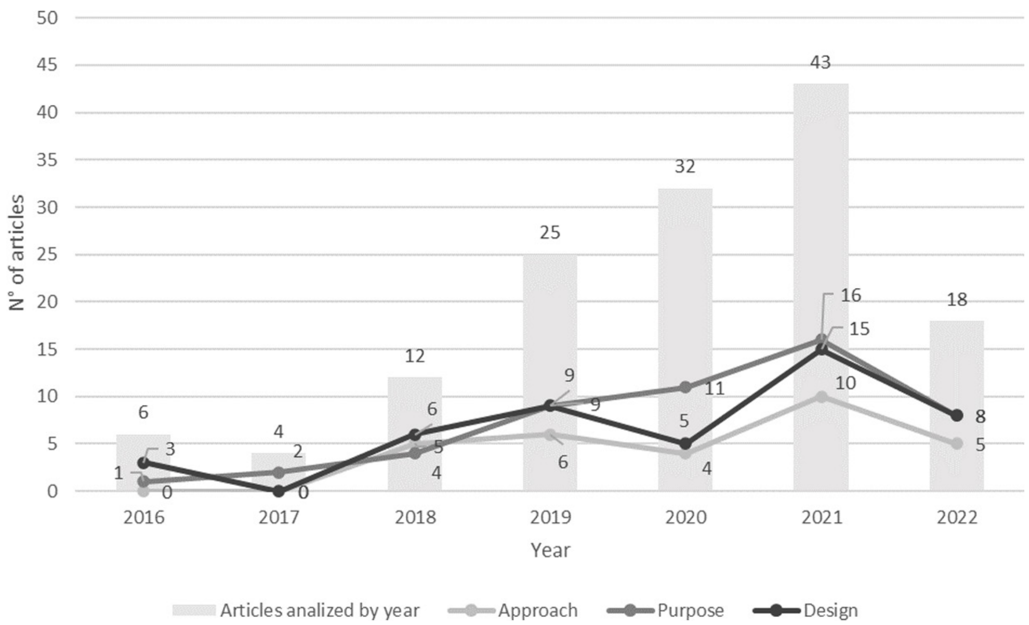

Fig. 6. Report of the pillars of methodological design segmented by years within the analyzed sample

Regarding the engineering knowledge fields, engineering education stands out as the one with more cases of explicit methodological design, as exhibited in Figure 7. In fact, 75% of the analyzed papers report the approach; 45%, the purpose; and 50%, the design. This may be due to the fact that engineering education as a research field is gradually building its own profile, drawing on research paradigms from natural, engineering, and social sciences [39]. Therefore, this field may collect the best research practices among these sciences. About the remaining knowledge fields, the reports of the pillars of methodological design vary from 0 to 30% regarding the approach, from 25 to 40% regarding the purpose, and from 20 to 35% regarding the design.

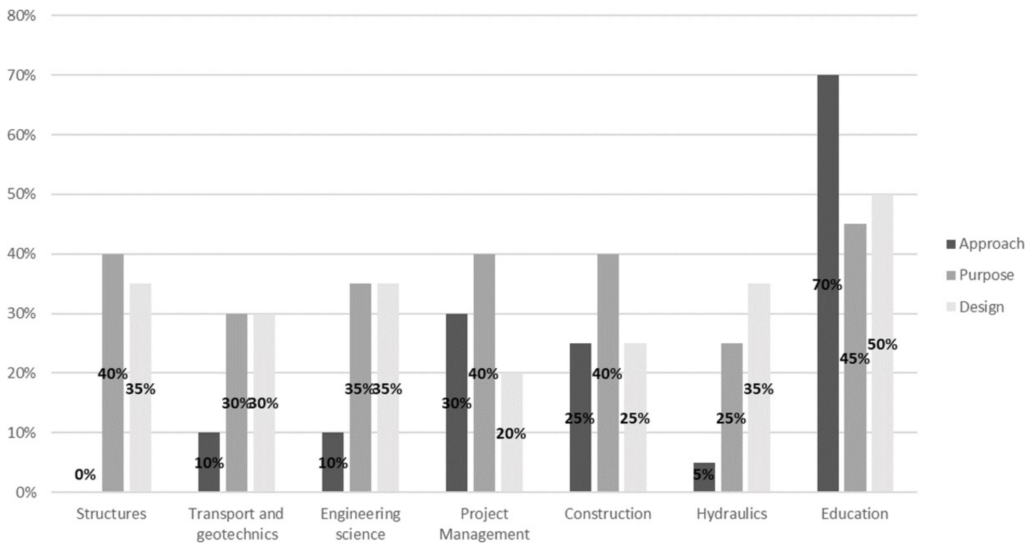

Fig. 7. Report of the pillars of methodological design segmented by knowledge field within the analyzed sample

About the approach, the most repeated in the sample is quantitative with 57%, as shown in Figure 8, followed by qualitative with 30%, and mixed with 13%. This may be explained considering that much of engineering studies are supported by numerical measurements and statistical analysis to prove hypotheses [44].

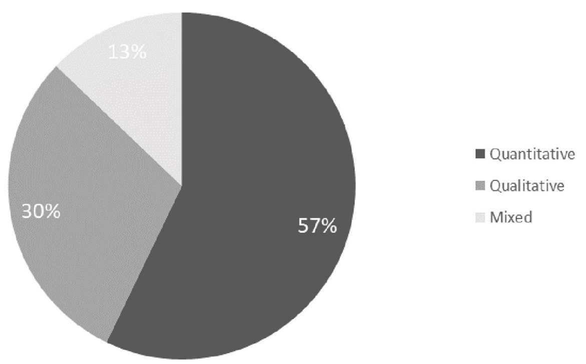

Fig. 8. Approaches found within the analyzed sample

About the purpose, descriptive research is the most repeated in the sample, as exhibited in Figure 9. In fact, 44% followed this purpose, while 35% followed an exploratory purpose, 11% a correlational purpose, and 10% an explanatory one. This diversity aligns with the examples in the Systematic Review section of the present research.

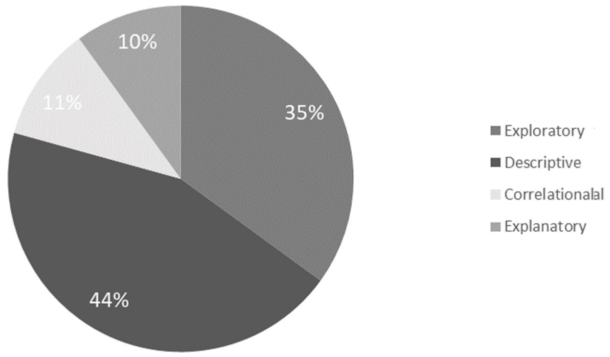

Fig. 9. Purposes found within the analyzed sample

About the design, within the sample, action research is the most featured with 45%, as illustrated in Figure 10. Action research is associated with the demonstration and evaluation of the feasibility of a proposed idea, such as the implementation of a technology, software, teaching approach, or evaluation instrument [39]. This research design is particularly common in the construction, engineering sciences, hydraulics, and engineering education knowledge fields. Experimental research follows, with 41%. Non-experimental research is less common, with 9% within the sample. Finally, grounded theory, ethnographic, and phenomenological research are the least common.

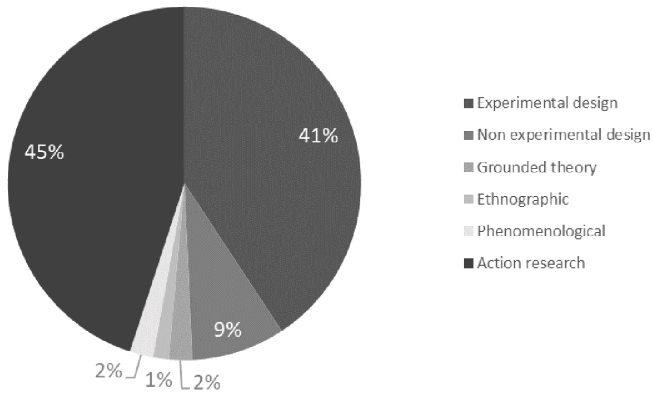

Fig. 10. Designs found within the analyzed sample

4.2 Framework proposal

The analysis of the results confirms the study hypothesis: most of the analyzed research papers corresponding to the engineering field lack an explicit methodological design. This statement can be supported by observing Figure 5, which reveals their approach, purpose, and design. Given the evident lack of an explicit methodological design within the sample and its relevance to the understanding of research, a framework was elaborated, expecting it may help the engineering students develop consistent research projects.

The framework is based on the literature review, which describes the pillars of methodological design, and is enriched with the data obtained from the sample. It follows the entire research process, as exposed in Figure 11. It also implies five phases, starting with the preliminary conceptual design and ending with the selection of data collection techniques and tools. The purpose is defined within phase I; the approach, within phase II; and the design, within phase III. These pillars allow decision-making upon the sample and data collection techniques and tools, which correspond to phases IV and V.

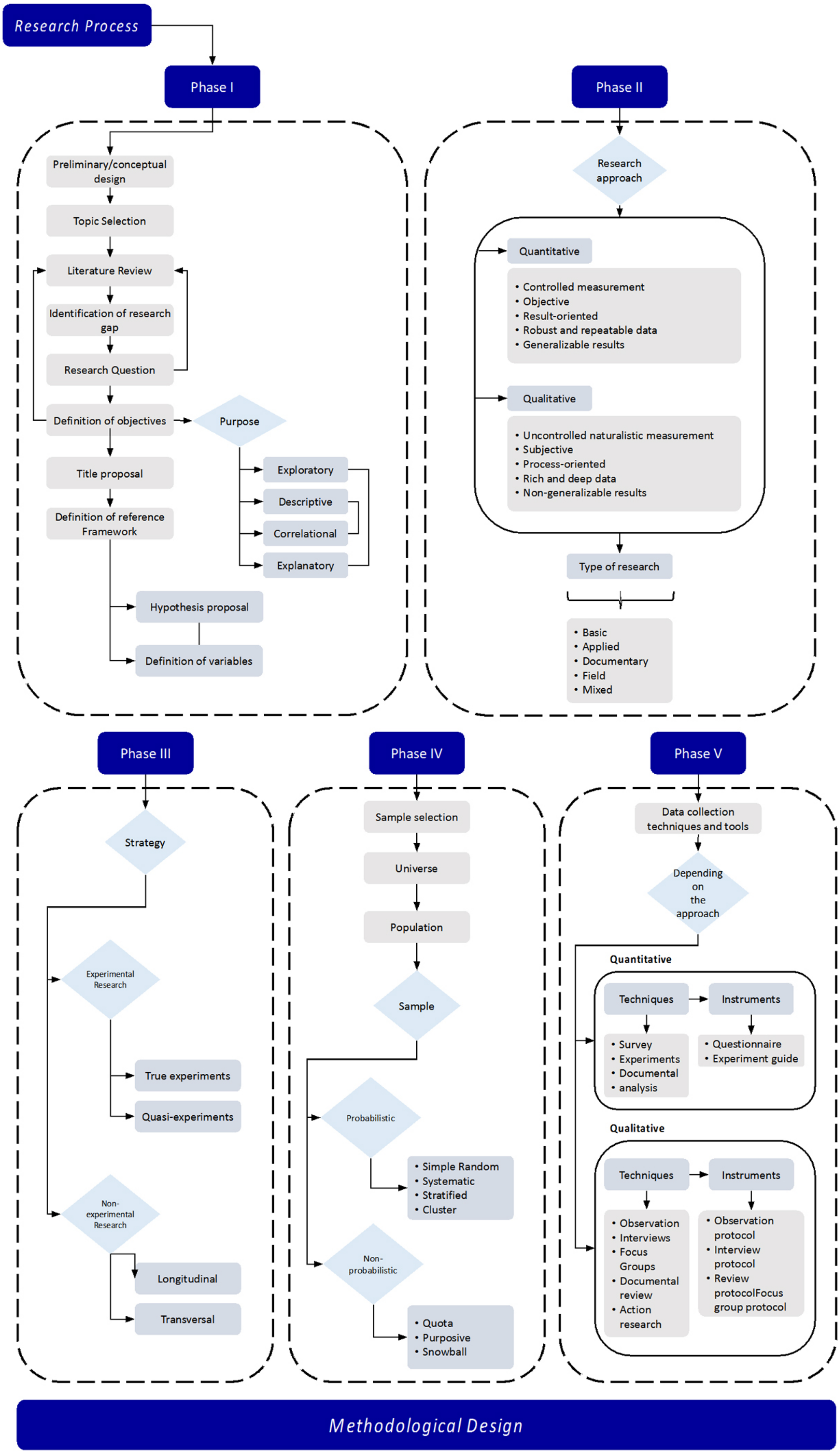

Fig. 11. Framework proposal for research methodological design process

5 CONCLUSIONS

The present research aimed to propose a framework for the identification, conceptualization, and proposal of a structured methodological design within research training exercises developed at engineering programs. It is expected to promote the proper use of research methodology among engineering students. This framework is organized upon the two main phases of every research process: design and execution. The objective of the study was motivated by the findings obtained from the analysis of a sample of engineering research papers: the lack of explicit methodological design. It was concluded that there is an apparent absence of it within the engineering field. Thus, it is also expected that the framework may help the community to unravel the methodological design among engineering papers that do not declare it.

In fact, from the analyzed 140 civil engineering research papers from the Scopus database-indexed journals, 94.29% did not explicitly present the methodological design. Thus, it must be inferred by the readers. From the 5.71% that stated it, engineering education stands out as the knowledge field with more explicit reports. In fact, 75% of the analyzed papers report the approach; 45%, the purpose; and 50%, the design. It is expected that this research practice may be replicated in the other engineering knowledge fields in the coming years.

Based on the obtained results from the analysis, it can be said the lack of an explicit methodological design in papers within engineering indexed journals could be associated with the inherent nature of this knowledge field, which faces the arising challenges posed by society's requirements and needs, according to the resources available. Therefore, during the development of research, the design execution may be subject to modifications based on the environment and available resources. Thus, researchers must rely on their ingenuity to overcome obstacles. In fact, ingenuity aligns with the etymology of the word "engineering," stemming from the Latin *ingenium*.

This analysis also aims to encourage research training actors to determine the level and scope of research so that a methodological design that meets the needs of the research is proposed. At the same time, the methodological design proposal for those who are now at the research training stage aims to contribute with structured lifelong learning research methods within their training. In any case, there is little concern within the engineering field about the formal presentation of research methodological design in indexed publications. However, as Figure 6 reveals, it should be noted that this is changing, as the trends through the years show an increase in the report of the methodological design. In this line, researchers should consider that a proper methodological design provides an added value to the research, as it ensures its replicability and consistency, which is an aspect evaluated among indexed journals when submitting a paper.

Nevertheless, given the importance of methodological design to allow the synergy within the R+D+i+e model and with it ensure the progress of science, technology, and knowledge, it is expected that an improvement will show up. In this line, future works may continue the follow-up of this process for transversal research. It should also be necessary to study Q3 and Q4 indexed journals, as only Q1 and Q2 journals were analyzed with no significant differences found. Journals with an H-index lower than 25 may also be studied to compare the obtained results. Additionally, other engineering fields, rather than civil, may also carry on similar studies with their particular knowledge fields.

The upgrades regarding the explicit statement of methodological design may also be supported by increasing requirements by the top-ranked journals, as results revealed major methodological rigor among Q1 and higher H-index journals. Consequently, it is likely that methodological design will be progressively taken into consideration by engineering researchers, which justifies the relevance of the presented study. Finally, it is expected that this research should serve as an information source for the engineering community who are eager to appropriately present their methodological design, to facilitate its adoption, and to promote its adequate use through the application of the proposed framework.

For future studies, it is suggested to review the relationship between the inclusion of research methodology content within the engineering curricula and the formal presentation of methodological design in the final documents published as theses and the possible papers derived from them to be published in indexed journals.

6 ACKNOWLEDGMENTS

The authors thank Universidad de Lima for providing access to indexed databases.

7 REFERENCES

[1] A. A. Del Savio, K. Galantini Velarde, B. Díaz-Garay, and E. Valcárcel Pollard, "A methodology for embedding Building Information Modelling (BIM) in an undergraduate civil engineering program," *Applied Sciences*, vol. 12, no. 23, p. 12203, 2022. https://doi.org/10.3390/app122312203

[2] L. Cangalaya, "Habilidades del pensamiento crítico en estudiantes universitarios a través de la investigación," *Desde el Sur*, vol. 12, no. 1, pp. 141–153, 2020. https://doi.org/10.21142/DES-1201-2020-0009

[3] J. K. Petrella and A. P. Jung, "Undergraduate research: Importance, benefits, and challenges," *International Journal of Exercise Science*, vol. 1, no. 3, pp. 91–95, 2008.

[4] A. A. Del Savio, L. M. Cáceres Montero, and K. Galantini Velarde, "A methodology for embedding research competencies in an undergraduate civil engineering program," *International Journal of Engineering Education,* vol. 37, no. 5, pp. 1201–1214, 2021. https://www.ijee.ie/contents/c370521.html

[5] J. S. Stanford, S. E. Rocheleau, K. P. W. Smith, and J. Mohan, "Early undergraduate research experiences lead to similar learning gains for STEM and Non-STEM undergraduates," *Studies in Higher Education*, vol. 42, no. 1, pp. 115–129, 2015. https://doi.org/10.1080/03075079.2015.1035248

[6] A. Brew, *Research and Teaching: Beyond the Divide*. London: Palgrave Macmillan, 2006. http://ci.nii.ac.jp/ncid/BA7838838X

[7] A. B. Hunter, S. Laursen, and E. Seymour, "Becoming a scientist: The role of undergraduate research in students' cognitive, personal, and professional development," *Science Education*, vol. 91, no. 1, pp. 36–74, 2007. https://doi.org/10.1002/sce.20173

[8] H. De Wit and P. G. Altbach, "Internationalization in higher education: Global trends and recommendations for its future," *Policy Reviews in Higher Education*, vol. 5, no. 1, pp. 28–46, 2021. https://doi.org/10.1080/23322969.2020.1820898

[9] M. Rabossi and A. Guaglianone, "Políticas de internacionalización universitaria en la Argentina: Movilidad estudiantil y producción científica," *Revista Ibero-Americana de Estudos em Educação*, vol. 15, no. 4, pp. 2556–2576, 2020. https://doi.org/10.21723/riaee.v15iesp4.14504

[10] R. Deem, K. H. Mok, and L. Lucas, "Transforming higher education in whose image? Exploring the concept of the 'world-class' university in Europe and Asia," *Higher Education Policy*, vol. 21, pp. 83–97, 2008. https://doi.org/10.1057/palgrave.hep.8300179

[11] R. Barnett, Ed., *Reshaping the University: New Relationship Between Research, Scholarship and Teaching*. London: Society for Research into Higher Education & Open University Press, 2005. http://ci.nii.ac.jp/ncid/BA74672199

[12] R. Lucas, "On the mechanics of economic development," *Journal of Monetary Economics*, vol. 22, no. 1, pp. 3–42, 1988. https://doi.org/10.1016/0304-3932(88)90168-7

[13] OECD, "Ministerial report on the OECD innovation strategy: Innovation to strengthen growth and address global and social challenges," 2010.

[14] A. Jiménez, "Relaciones universidad-empresa: Hacia una productividad basada en innovación," *Gestión y Tendencias*, vol. 1, no. 2, pp. 7–10, 2016. https://doi.org/10.11565/gesten.v2i1.11

[15] D. P. Montero and M. J. C. Tarazona, "Cooperative learning: A methodological innovation in teacher training / El aprendizaje cooperativo: una innovación metodológica en la formación del profesorado," *Culture And Education,* vol. 28, no. 2, pp. 378–395, 2016. https://doi.org/10.1080/11356405.2016.1158448

[16] V. L. Hesli and J. M. Lee, "Faculty research productivity: Why do some of our colleagues publish more than others," *PS: Political Science & Politics,* vol. 44, no. 2, pp. 393–408, 2011. https://doi.org/10.1017/S1049096511000242

[17] J. Lindner, "Entrepreneurship education for a sustainable future," *Discourse and Communication for Sustainable Education*, vol. 9, no. 1, pp. 115–127, 2018. https://doi.org/10.2478/dcse-2018-0009

[18] National Science Board (NSB) and National Science Foundation (NSF), "Science and engineering indicators 2020," NSB-2020-6. Alexandria, VA, 2019. Recovered from: https://ncses.nsf.gov/pubs/nsb20206/

[19] T. Ramírez and A. Salcedo, "América Latina y la producción de artículos científicos: Un crecimiento desigual y asimétrico," *Práxis Educacional*, vol. 19, no. 50, p. e12001, 2023. https://doi.org/10.22481/praxisedu.v19i50.12001

[20] National Science Board (NSB), "Science & Engineering Indicator 2018," NSB-2020-6. Alexandria, VA, 2018. Recovered from: https://www.nsf.gov/statistics/2018/nsb20181/report/sections/higher-education-in-science-and-engineering/international-s-e-higher-education

[21] C. Carberry *et al*., "Curriculum initiatives to enhance research skills acquisition by medical students: A scoping review," *BMC Medical Education*, vol. 21, 2021. https://doi.org/10.1186/s12909-021-02754-0

[22] K. M. Cooper, J. M. Cala, and S. E. Brownell, "Cultural capital in undergraduate research: An exploration of how biology students operationalize knowledge to access research experiences at a large, public research-intensive institution," *International Journal of STEM Education*, vol. 8, 2021. https://doi.org/10.1186/s40594-020-00265-w

[23] Z. Öcek *et al*., "Research training program in a Turkish medical school: Challenges, barriers and opportunities from the perspectives of the students and faculty members," *BMC Medical Education*, vol. 21, 2021. https://doi.org/10.1186/s12909-020-02454-1

[24] C. J. Faber, R. L. Kajfez, D. M. Lee, L. C. Benson, M. S. Kennedy, and E. G. Creamer, "A grounded theory model of the dynamics of undergraduate engineering students' researcher identity and epistemic thinking," *Journal of Research in Science Teaching*, vol. 59, no. 4, pp. 529–560, 2021. https://doi.org/10.1002/tea.21736

[25] S. E. Branch, A. Woodcock, and W. G. Graziano, "Person orientation and encouragement: Predicting interest in engineering research," *Journal of Engineering Education*, vol. 104, no. 2, pp. 119–138, 2015. https://doi.org/10.1002/jee.20068

[26] M. Beckman and N. Hensel, "Making explicit the implicit: Defining undergraduate research," *CUR Quarterly*, vol. 29, no. 4, pp. 40–44, 2009.

[27] E. M. L. S. de Alencar and Z. M. F. de Oliveira, "Creativity in higher education according to graduate programs' professors," *Universal Journal of Educational Research*, vol. 4, no. 3, pp. 555–560, 2016. https://doi.org/10.13189/ujer.2016.040312

[28] M. Healey, "Linking research and teaching: Exploring disciplinary spaces and the role of inquiry-based learning," in *Reshaping the University: New Relationships Between Research, Scholarship and Teaching*, R. Barnett, Ed., Maidenhead, UK: Open University Press, pp. 30–42, 2005.

[29] K. Zimbardi and P. Myatt, "Embedding undergraduate research experiences within the curriculum: A cross-disciplinary study of the key characteristics guiding implementation," *Studies in Higher Education*, vol. 39, no. 2, pp. 233–250, 2014. https://doi.org/10.1080/03075079.2011.651448

[30] H. K. Ro, D. Merson, L. R. Lattuca, and P. T. Terenzini, "Validity of the contextual competence scale for engineering students," *Journal of Engineering Education*, vol. 104, no. 1, pp. 35–54, 2015. https://doi.org/10.1002/jee.20062

[31] J. Walther, N. Kellam, N. W. Sochacka, and D. Radcliffe, "Engineering competence? An interpretive investigation of engineering students' professional formation," *Journal of Engineering Education*, vol. 100, no. 4, pp. 703–740, 2011. https://doi.org/10.1002/j.2168-9830.2011.tb00033.x

[32] S. W. Rogers and R. K. Goktas, "Exploring engineering graduate student research proficiency with student surveys," *Journal of Engineering Education*, vol. 99, no. 3, pp. 263–278, 2010. https://doi.org/10.1002/j.2168-9830.2010.tb01061.x

[33] F. A. Phang and K. M. Yusof, "Taking the 'Guess-work' out of engineering education: Establishing the virtuous cycle of research," *Procedia – Social and Behavioral Sciences*, vol. 102, pp. 212–220, 2013. https://doi.org/10.1016/j.sbspro.2013.10.735

[34] J. Noguez and L. Neri, "Research-based learning: A case study for engineering students," *International Journal on Interactive Design And Manufacturing*, vol. 13, no. 4, pp. 1283–1295, 2019. https://doi.org/10.1007/s12008-019-00570-x

[35] R. Joedodibroto, "Some experiences in training engineering students for a better information seeking methodology," *European Journal of Engineering Education*, vol. 16, no. 3, pp. 261–263, 1991. https://doi.org/10.1080/03043799108939529

[36] J. González, N. Galindo, J. Galindo, and M. Gold, "Los paradigmas de la calidad educativa," De la autoevaluación a la acreditación, Mexico City: Union of Latin American Universities, 2004.

[37] R. H. Sampieri, C. F. Collado, and P. B. Lucio, *Metodología de la Investigación*. Ciudad de México, México: McGraw-Hill, 2015.

[38] R. Wieringa and J. M. Heerkens, "The methodological soundness of requirements engineering papers: A conceptual framework and two case studies," *Requirements Engineering*, vol. 11, no. 4, pp. 295–307, 2006. https://doi.org/10.1007/s00766-006-0037-6

[39] L. Malmi *et al.*, "How authors did it – A methodological analysis of recent engineering education research papers in the European journal of engineering education," *European Journal of Engineering Education*, vol. 43, no. 2, pp. 171–189, 2018. https://doi.org/10.1080/03043797.2016.1202905

[40] L. Burton, "Methodology and methods in mathematics education research: Where is 'The Why'?" in *Researching Mathematics Classrooms: A Critical Examination of Methodology*, S. Goodchild and L. English, Eds., Westport, CT: Praeger, pp. 1–10. 2002. https://doi.org/10.5040/9798216007920.0006

[41] A. Pulido-Rojano, "Methodological design for the prevention of risk in production processes," *Dyna-colombia*, vol. 82, no. 193, pp. 16–22, 2015. https://doi.org/10.15446/dyna.v82n193.42903

[42] P. Farrugia, B. A. Petrisor, F. Farrokhyar, and M. Bhandari, "Research questions, hypotheses and objectives," *Canadian Journal of Surgery*, vol. 53, no. 4, pp. 278–281, 2010. https://www.ncbi.nlm.nih.gov/pmc/articles/PMC2912019/

[43] J. Brannen, "Mixing methods: The entry of qualitative and quantitative approaches into the research process," *International Journal of Social Research Methodology*, vol. 8, no. 3, pp. 173–184, 2005. https://doi.org/10.1080/13645570500154642

[44] K. Hammarberg, M. Kirkman, and S. De Lacey, "Qualitative research methods: When to use them and how to judge them," *Human Reproduction*, vol. 31, no. 3, pp. 498–501, 2016. https://doi.org/10.1093/humrep/dev334

[45] K. Niglas, *The Multidimensional Model of Research Methodology: An Integrated Set of Continua*. Thousand Oaks, CA: SAGE Publications, 2010. https://doi.org/10.4135/9781506335193.n9

[46] M. Borrego, E. P. Douglas, and C. T. Amelink, "Quantitative, qualitative, and mixed research methods in engineering education," *Journal of Engineering Education*, vol. 98, no. 1, pp. 53–66, 2009. https://doi.org/10.1002/j.2168-9830.2009.tb01005.x

[47] P. Leedy and J. Ormrod, *Practical Research: Planning and Design*. Thousand Oaks, CA: SAGE Publications, 2001.

[48] J. Creswell, *Research Design: Qualitative, Quantitative and Mixed Methods Approaches* (2nd ed.). Thousand Oaks, CA: SAGE Publications, 2003.

[49] C. Williams, "Research methods," *Journal of Business & Economics Research*, vol. 5, no. 3, 2007. https://doi.org/10.19030/jber.v5i3.2532

[50] M. Koro-Ljungberg and E. P. Douglas, "State of qualitative research in engineering education: Meta-analysis of JEE articles, 2005–2006," *Journal of Engineering Education*, vol. 97, no. 2, pp. 163–175, 2008. https://doi.org/10.1002/j.2168-9830.2008.tb00965.x

[51] M. V. Carrillo-Durán and Pérez M. Pulido, *Cases on Developing Effective Research Plans for Communications and Information Science*. Hershey, PA: IGI Global, 2022. https://doi.org/10.4018/978-1-6684-4523-5

[52] H. Nassaji, "Qualitative and descriptive research: Data type versus data analysis," *Language Teaching Research*, vol. 19, no. 2, pp. 129–132, 2015. https://doi.org/10.1177/1362168815572747

[53] M. K. Asamoah, "Re-examination of the limitations associated with correlational research," *Journal of Educational Research and Reviews*, vol. 2, no. 4, pp. 45–52, 2014. http://www.sciencewebpublishing.net/jerr/archive/2014/July/pdf/Asamoah.pdf

[54] E. Wentz, *How to Design, Write, and Present a Successful Dissertation Proposal*. Thousand Oaks, CA: SAGE Publications, 2014. https://doi.org/10.4135/9781506374710

[55] S. B. Merriam, "Introduction to qualitative research," *Qualitative Research in Practice: Examples for Discussion and Analysis*, vol. 1, no. 1, pp. 1–17, 2002.

[56] W. R. Shadish, T. D. Cook, and D. T. Campbell, *Experimental and Quasi-Experimental Designs for Generalized Causal Inference* (2nd ed.). New York: Houghton Mifflin, 2002.

[57] D. W. Fiske and S. T. Fiske, "Laboratory studies," *Encyclopedia of Social Measurement*, pp. 435–439, 2005. https://doi.org/10.1016/B0-12-369398-5/00407-2

[58] A. T. Mısırlı, A. Bener, B. Çağlayan, G. Çalıklı, and B. Turhan, "Field studies: A methodology for construction and evaluation of recommendation systems in software engineering," in *Recommendation Systems in Software Engineering*, 2014, pp. 329–355. https://doi.org/10.1007/978-3-642-45135-5_13

[59] H. J. Seltman, *Experimental Design and Analysis*. Pittsburgh, PA: Carnegie Mellon University, 2012.

[60] D. M. Dimitrov, *Quantitative Research in Education*. New York, NY: Whittier Publications, 2008.

[61] H. White and S. Sabarwal, "Quasi-experimental design and methods: Methodological briefs – impact evaluation No. 8," RePEc: Research Papers in Economics, 2014. https://econpapers.repec.org/RePEc:ucf:metbri:innpub753

[62] I. Iskhakov, Y. Ribakov, K. Holschemacher, and S. Kaeseberg, "Experimental case study for practical implementation of real pre-stressed two layer reinforced concrete beams," *Structures*, vol. 47, pp. 1284–1294, 2023. https://doi.org/10.1016/j.istruc.2022.11.084

[63] T. G. Reio, "Nonexperimental research: Strengths, weaknesses and issues of precision," *European Journal of Training and Development*, vol. 40, nos. 8–9, pp. 676–690, 2016. https://doi.org/10.1108/EJTD-07-2015-0058

[64] E. J. Caruana, M. Roman, J. Hernández-Sánchez, and P. Solli, "Longitudinal studies," *PubMed*, vol. 7, no. 11, pp. E537–E540, 2015. https://doi.org/10.3978/j.issn.2072-1439.2015.10.63

[65] K. A. Levin, "Study design III: Cross-sectional studies," *Evidence-Based Dentistry*, vol. 7, no. 1, pp. 24–25, 2006. https://doi.org/10.1038/sj.ebd.6400375

[66] A. Bazargan, M. Nejati, H. Hajikhani, Z. Shafiei, and R. A. Mehrizi, "Cross sectional study of the top research topics in environmental science and engineering," *Results in Engineering*, vol. 14, p. 100465, 2022. https://doi.org/10.1016/j.rineng.2022.100465

[67] B. Fitzgerald and T. O'Kane, "A longitudinal study of software process improvement," *IEEE Software*, vol. 16, no. 3, pp. 37–45, 1999. https://doi.org/10.1109/52.765785

[68] N. J. Petty, O. P. Thomson, and G. Stew, "Ready for a paradigm shift? Part 2: Introducing qualitative research methodologies and methods," *Manual Therapy*, vol. 17, no. 5, pp. 378–384, 2012. https://doi.org/10.1016/j.math.2012.03.004

[69] H. Sharp, Y. Dittrich, and C. R. B. De Souza, "The role of ethnographic studies in empirical software engineering," *IEEE Transactions on Software Engineering*, vol. 42, no. 8, pp. 786–804, 2016. https://doi.org/10.1109/TSE.2016.2519887

[70] V. Troesch, "A phenomenological approach to teaching engineering ethics," in *IEEE International Symposium on Ethics in Science, Technology and Engineering*, 2014, pp. 1–9. https://doi.org/10.1109/ETHICS.2014.6893434

[71] M. Ispizua and C. Lavía, *LA Investigación Como Proceso. Planificación y desarrollo* (Primera ed.). Madrid, España: Dextra Editorial, SL, 2016.

[72] A. Cruz Novoa, "Innovación de Base Científica-Tecnológica desde las Universidades de Iberoamérica," *Journal of Technology Management & Innovation*, vol. 11, no. 4, pp. 1–4, 2016. https://doi.org/10.4067/S0718-27242016000400001

[73] Journal Citation Reports. Clarivate, 2023. https://clarivate.com/products/scientific-and-academic-research/research-analytics-evaluation-and-management-solutions/journal-citation-reports/

[74] K. Orbay, R. Miranda, and M. Orbay, "INVITED ARTICLE: Building journal impact factor quartile into the assessment of academic performance: A case study," *Participatory Educational Research*, vol. 7, no. 2, pp. 1–13, 2020. https://doi.org/10.17275/per.20.26.7.2

[75] E. Roldan-Valadez, U. Orbe-Arteaga, and C. Ríos, "Eigenfactor score and alternative bibliometrics surpass the impact factor in a 2-years ahead annual-citation calculation: A linear mixed design model Analysis of radiology, nuclear medicine and medical imaging journals," *Radiologia Medica*, vol. 123, no. 7, pp. 524–534, 2018. https://doi.org/10.1007/s11547-018-0870-y

[76] A. Kirby, "Exploratory bibliometrics: Using VOSViewer as a preliminary research tool," *Publications*, vol. 11, no. 1, p. 10, 2023. https://doi.org/10.3390/publications11010010

[77] M. Borrego, "Development of engineering education as a rigorous discipline: A study of the publication patterns of four coalitions," *Journal of Engineering Education*, vol. 96, no. 1, pp. 5–18, 2007. https://doi.org/10.1002/j.2168-9830.2007.tb00911.x

[78] M. D. Lindner, K. D. Torralba, and N. A. Khan, "Scientific productivity: An exploratory study of metrics and incentives," *PLoS ONE*, vol. 13, no. 4, p. e0195321, 2018. https://doi.org/10.1371/journal.pone.0195321

[79] R. Wieringa and J. M. Heerkens, “The methodological soundness of requirements engineering papers: A conceptual framework and two case studies,” *Requirements Engineering*, vol. 11, pp. 295–307, 2006. https://doi.org/10.1007/s00766-006-0037-6

8 AUTHORS

Alexandre Almeida Del Savio has a Ph.D. in Civil Engineering from the Pontifical Catholic University of Rio de Janeiro, a mentor certificate in Virtual Design and Construction (VDC) from Stanford University, and over 22 years of experience. He is a researcher and Full Professor of the Civil Engineering Department and Head of the Scientific Research Institute at *Universidad de Lima*. He is particularly interested in VDC, BIM, Integrating Project Delivery (IPD), Integrated Concurrent Engineering (ICE), Project Production Management (PPM), civil engineering competency-based curriculum, Project-Based Learning (PBL), construction automation and industrialization, construction technology, transportation, computer vision, artificial intelligence, and machine learning.

Katerina Galantini Velarde is a doctoral candidate in higher education at Universidad de Palermo. She has a Masters in Education by *Universidad Femenina del Sagrado Corazón* and an architect by *Universidad de Lima.* She is a Professor for the Architecture Faculty and a researcher for the Scientific Research Institute at the *Universidad de Lima,* Peru. Her research interests include undergraduate research training, undergraduate curriculum design and management, engineering and design pedagogy, and formative assessment (E-mail: kgalanti@ulima.edu.pe).

Ludy Cáceres Montero is a Doctor in Material Engineering *by Pontifícia Universidade Católica do Rio de Janeiro.* Chemical engineer and Master in Material Engineering. She is a professor and researcher at *Universidad de Lima*.

Mónica Alejandra Vergara Olivera is a Master’s in Project Management student at *Universidad ESAN*. She is an architect, researcher and a teaching assistant at *Universidad de Lima.*