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RESEARCH METHODOLOGIES IN ENGINEERING SCIENCES: A CRITICAL ANALYSIS

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Abstract: *This study evaluates the research methodologies utilized in the engineering sciences. The primary goal is to identify best practices in research design, data acquisition, and result interpretation to suggest future engineering research. A systematic literature review evaluated the methodological approaches and trends of studies published over the past decade. The study's methodology included article selection based on predefined criteria, data extraction on research design, data collection and analysis methods, and result communication. The results revealed a variety of approaches and techniques, with quantitative research predominating, although an increase in the use of qualitative and blended methods was also noted. There were identified trends in research design, data acquisition and analysis, and communication*

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of results that reflect the evolution and requirements of the engineering field. This study concludes by emphasizing the significance of understanding and employing various approaches and techniques in engineering research to address the field's complex and interdisciplinary problems effectively. By promoting methodological diversity and adopting best practices in research design, data collection and analysis, and result communication, engineering researchers and professionals can improve the quality and impact of their research and make significant contributions to advancing engineering knowledge and problem-solving.
Keywords: *A examined Engineering, research methodology, methods for engineering, engineering sciences*

Introduction

Formulating distinct and pertinent research questions is crucial to selecting and applying appropriate research methodologies in the field of engineering sciences (Kitchenham & Charters, 2007). When selecting the most appropriate methodological approach, researchers must carefully consider the objectives of their studies and the characteristics of their research field (Creswell, 2012). In addition, it is essential to appropriately design the sample, sampling, and research instruments to ensure the collected data's validity and dependability (Fink, 2013; Trochim & Donnelly, 2006). In this regard, surveys and questionnaires, observations and measurements, interviews, and document and record analysis, among other methods, can be utilized based on the specific requirements of each study (Bowen, 2009; Dillman, Smyth, & Christian, 2014; Seidman, 2013; Stebbins, 2001). The engineering disciplines encompass civil engineering, mechanical engineering, electrical engineering, and numerous others. These disciplines require exhaustive research methodologies to investigate and address such complex issues. The purpose of semi-systematic reviews is not only to provide an overview of a subject but also to trace the subject's evolution across various disciplinary frameworks and periods (Al Qurishee et al., 2020). The overarching objective of the review is to discover and comprehend all potentially pertinent research traditions that have implications for the examined issue and to synthesize them using meta-narratives instead of evaluating impact size. Through this, complex topics become transparent. The central tenet of this methodology is that studies should be as transparent and reproducible as possible, with well-considered research strategies that allow readers to evaluate the validity of the authors' claims. An appropriate study methodology impedes research, data collection, and conclusion writing (Mshangi, Nfuka, & Sanga, 2017). The research query, available materials, and other limitations all play a role in determining the methods employed.

Given its emphasis on objective measurement and statistical analysis of numerical data, the quantitative approach has long been the dominant research methodology in engineering sciences (Creswell & Creswell, 2017). Despite its prevalence, quantitative research is not always appropriate for addressing all research questions in engineering, leading to the emergence of qualitative and design approaches that investigate more descriptive and contextual aspects of the studied phenomena (Cross, 2007; Stake, 2010). Using techniques such as interviews and observations, qualitative research, for instance, seeks to comprehend the experiences and perspectives of participants (Denzin & Lincoln, 2011). Design research, on the other hand, concentrates on developing and evaluating innovative engineering solutions to address real-world issues (Van Aken & Romme, 2009).

Experimental approaches aim to investigate a system by systematically altering one or more constituent elements and measuring the resulting changes. Creating prototypes or experimental configurations in the laboratory is a typical step in these procedures. Experiments allow for the exhaustive examination of hypotheses and the collection of numerical data. In light of established or developing disciplines of study, most attempts to synthesize existing knowledge are undertaken. In the context of designed themes, an integrated review approach aims to provide an overview of the extant body of knowledge, critically examine and possibly re-conceptualize it, and expand on its theoretical foundation. Rather than reviewing existing models, the objective for newly emerging issues is to develop fundamental or rudimentary conceptualizations and theoretical frameworks. As its objective is typically not to include every article ever written on the subject but to combine perspectives and insights from diverse domains or research traditions, this review frequently requires a more creative approach to data collection. However, they can be expensive, time-consuming, and impractical for certain engineering investigation problems.

In recent years, mixed research methodologies, which combine quantitative and qualitative approaches, have increased in engineering sciences (Creswell & Plano Clark, 2017; Johnson & Onwuegbuzie, 2004). These diverse approaches provide a more comprehensive comprehension of the phenomenon under study and enable researchers to address more complex and multifaceted research questions. Moreover, experimental and non-experimental research, such as case studies and comparative methods, have proved useful in engineering for exploring causal relationships and developing theories (Shadish, Cook, & Campbell, 2002; Yin, 2017).

Data analysis in engineering sciences has also evolved, integrating an extensive array of techniques ranging from statistical and qualitative research to network and dynamic systems analysis (Arias Gonzáles, Covinos Gallardo, & Cáceres Chávez, 2022; Braun & Clarke, 2006; Field, 2013; Sterman, 2000; Wasserman & Faust, 1994). Engineering has benefited greatly from implementing modeling and simulation techniques in addressing complex problems and facilitating decision-making (Law, 2013). Effective communication of results, including the appropriate presentation of quantitative and qualitative data, data visualization, report writing, and article publication, is essential for the dissemination and impact of research findings in the scientific community and society at large (Heiberger & Robbins, 2014; Swales & Feak, 2012; Tracy, 2019; Tufte, 2001).

What could a comprehensive review possibly contribute to the field? An integrative review should generate novel insights and theoretical frameworks instead of merely summarizing or delineating a field of study. Instead of providing prior information, the paper should propose a novel theoretical framework. Even though there are numerous possible approaches, researchers are expected to adhere to established conventions when reporting the methods used to conduct an integrative review. There are currently three primary types of coverage available. First, all relevant publications, both published and unpublished, must be incorporated into the analysis to ensure that the results are derived from a vast pool of data. The second style of the jacket contains elements typical of most other books in the same genre. According to Abbas (2016), when authors employ this strategy, they search a limited number of high-impact journals for relevant articles.

Consequently, describing the integration process and selection criteria for the included papers is essential. Integrative reviews are frequently marred by a lack of transparency or genuine integration of research, despite the potential value and efficacy of their contributions to their respective fields of study. Many purportedly

integrative evaluations are merely literature assessments (Danku & Antwi, 2020).

This article examines the evolution and applicability of the research methodologies employed in engineering sciences (Kumar & Phrommathed, 2005) and critically analyzes their use. Creswell (2014) examines emerging trends and established practices in research design, data acquisition, and interpretation of results through a comprehensive literature review. This analysis provides a solid foundation for understanding the most effective research methodologies in engineering sciences and recommending future research in this field (Snyder, 2019). The primary objective is to identify best practices in research design, data acquisition, and result interpretation to suggest future engineering research.

Literature Review

The literature review on research methodologies in engineering sciences focuses on five essential areas: methodological approaches, research design, data collection, data analysis, and results communication. Below is a compendium of the literature in each of these fields.

Empirical literature review

The results obtained using this methodology demonstrate that it is possible to adhere to a strict procedure to obtain results relevant to the study's topic, research questions, inclusion and exclusion criteria, and analysis. Computer models are created and utilized to simulate and model engineering systems in the actual world. Researchers can use these techniques to simulate various events, evaluate system performance, and refine their creations (Abbas, 2016; Kgabi, 2014; Tao, 2015). Simulation and modeling techniques are extensively utilized in the fields of transportation engineering, electrical systems, and manufacturing. However, the dependability of simulations depends on the accuracy of the data used to construct them and the thoroughness of the validation process. This approach inherits these benefits and possibilities of immense impact through a methodical search procedure, supplemented by conceptual thinking components to reduce the researcher's workload (Al Kilani & Kobziev, 2016). Therefore, we recommend optimizing the process so that the initial phase of the systematic review is as productive as feasible. In addition, a list of high-impact journals is compiled, which serves as a platform for the new researcher to disseminate their findings, develop professional relationships with subject matter experts, and maintain a state of constant knowledge advancement.

Existing techniques provide a comprehensive account of the departure from empirical practices and overcoming previous constraints during the systematic creation of the state-of-the-art. The proposals by Sampaio, Gomes, and Farinha (2021), implemented by the same author in the search for literature reviews in engineering; and in later years, adapted by Hyman and Li (2018) and thousands of researchers, have served as a guide for researchers in recent years. One may employ a more targeted strategy, such as investigating the correlation or influence between two variables, or a more comprehensive one, examining the entire corpus of data in a particular field. A literature review is also useful when an overview of a topic or research challenge is required. This type of literature review is typically conducted to assess the present level of comprehension of a particular topic. You can use it to discuss an issue, create a research agenda, or identify knowledge deficits. They divide

it into three stages: planning, execution, and evaluation. Based on earlier ideas (Tao, 2015), the Kitchenham group at Keele University, as cited by Philip et al. (2010), develops the Guidelines for conducting Systematic Literature Reviews in Software Engineering, tailoring them to the specific needs of Software Engineering while making them applicable to other fields (Philip et al., 2010). To effectively employ these methods, a researcher must have extensive background knowledge and expertise in the scientific field in which they aim to advance state of the art.

Computational algorithms and simulations are the foundation of numerical approaches, which are utilized to solve intractable engineering problems. These methods employ computational programs and mathematical models to solve intractable equations approximatively. What can we anticipate a systematic review to contribute? A systematic review has the potential to contribute value in multiple ways. We can determine, for example, if an effect is consistent across trials and what type of follow-up research is required to establish it (Krall & Menzies, 2012). Studies can be contrasted across cultural contexts to determine whether there are significant differences in results, and techniques can be used to identify which aspects of the research or sample are influential. Numerous scientific disciplines, including optimization, computational fluid dynamics, and finite element analysis, rely significantly on numerical methods. They enable the analysis of complex systems, but their accuracy is contingent on the validity of the underlying mathematical models and the discretization techniques employed.

Methodological Approaches

Over time, research methodologies in engineering sciences have shifted from quantitative approaches (Creswell & Creswell, 2017) to qualitative approaches (Stake, 2010) and design approaches (Cross, 2007). In addition, action research (Coghlan & Brannick, 2014) and case studies (Yin, 2017) have gained prominence in evaluating engineering solutions and developing theories. Adopting mixed methods (Creswell & Plano Clark, 2017) and combining experimental and non-experimental research methodologies (Shadish et al., 2002) have enabled researchers to address more complex research questions and better understand the phenomena being investigated. Case study approaches involve investigating concrete examples or cases to understand complex engineering issues better. Interviews, observations, and document analysis are typical methods for acquiring qualitative data in these approaches. Although case study data can be comprehensive and contextualized, their applicability may be limited to specific circumstances (Lenka & Choudhury, 2011). Even though it can be difficult to determine which approach is most appropriate for a particular review, the research topic and the review's unique objective will always determine the optimal methodology. Survey methodologies use questionnaires and in-person interviews to collect data from a cross-section of a representative population. Questionnaires can be extremely useful for collecting statistically significant data on how people feel, think, and act about engineering phenomena (Krall & Menzies, 2012). Transportation planners, environmental scientists, engineers, and human factors designers frequently employ them. Survey methodologies utilize self-reported data, which may introduce biases and limitations. A systematic review is a gold standard for gathering articles because it provides confidence that every significant piece of information has been included. However, it is unsuitable for all projects and requires a specific research query. Gao, Yuan, and Du (2011) compare critical introspection to the reflexivity needed to conduct qualitative research. Although it is not typical for authors of literature reviews to reflect on the assumptions, beliefs, or values that may have influenced their interpretations, the reader may be able to do so by examining the authors' disciplinary field(s), research question(s), and stated study limitations. As this type

of research evolves, readers may expect authors to provide critical reflection (Gao et al., 2011).

A critical analysis approach provides the methodological rigor required to contribute substantially to a field, regardless of the literature review strategy used. (a) deconstruction, in which the studies to be reviewed are dissected into discrete data points or variables (e.g., breastfeeding duration, study design, sampling methods); (b) analysis, in which both cross-case comparisons and within-case analyses are conducted on the aggregated data for each variable. c) the reconstruction phase (Gao et al., 2011; Wang & Guo, 2012; Zięba, 2018) involves a meaningful synthesis of relationships between variables and creating new information that is greater than the sum of its elements. The procedure for analyzing qualitative research is similar, with analysts paying close attention to potential bias at each stage. We will address the possibility of systematic bias at each stage of the analysis process. In this situation, a semi-systematic review can be useful, but it is also more difficult because there are fewer apparent steps. However, systematic review methods are transparent and rigorously adhere to established standards and guidelines.

Research Design

Research design in engineering sciences necessitates formulating research questions and selecting appropriate research methods (Creswell, 2012; Kitchenham & Charters, 2007). Research objectives and the study field's characteristics should inform the methodology selection. Decisions regarding sample and sampling (Trochim & Donnelly, 2006) and the design of research instruments (Fink, 2013) are also essential for ensuring the quality and applicability of research results.

Data Collection

Surveys and questionnaires (Dillman et al., 2014), observations and measurements (Stebbins, 2001), interviews (Seidman, 2013), and analysis of documents and records (Bowen, 2009) are among the data collection methods utilized in engineering sciences. The methodological approach and the research questions determine the selection of data collection methods. Digital technologies and advancements in modeling and simulation (Law, 2013) have also impacted engineering data collection.

Data Analysis

Statistical analysis (Field, 2013), qualitative analysis (Braun & Clarke, 2006), network analysis (Wasserman & Faust, 1994), and dynamic systems analysis (Sterman, 2000) are just a few of the data analysis techniques utilized in engineering sciences. It is necessary to employ appropriate data analysis techniques to derive meaningful conclusions from collected data. In engineering, using specialized software, such as statistical analysis applications (Ihaka & Gentleman, 1996) and qualitative analysis software (Jackson & Bazeley, 2019), facilitates data processing and analysis. Using modeling and simulation techniques (Banks et al., 2010) has also contributed to advancements in decision-making and the resolution of complex problems in this field.

All cited books concur that research into the design is important due to the increasing number of Ph.D. programs that could benefit from familiarity with it. However, many of the examples and discussions presented at the book's center are on research through/by design instead of research in engineering design. In this paper, we offer a different strategy

for illuminating these interrelationships by summarizing and categorizing research papers on research in Engineering Design according to their objectives and contributions, methods and approaches, data collection techniques, and research instruments. These methods allow for data triangulation and may provide a more comprehensive perspective. In the engineering sciences, mixed-methods methodologies excel when investigating complex, multidimensional research topics. However, they may increase the complexity of data analysis and the necessity of cautiously integrating multiple approaches. The iterative development and evaluation of innovative engineering solutions are at the core of design research approaches. These methods advance engineering methodology by combining theoretical study with practical application. Industrial designers, product developers, and systems engineers regularly employ design research methods. However, they may require much effort and funds to be effective.

Communication of Results

Effective communication of research findings in engineering sciences is essential for maximizing their impact on the scientific community and society (Swales & Feak, 2012). Researchers must present their findings straightforwardly and understandably by utilizing appropriate data visualizations (Ramos et al., 2022; Tufte, 2001) and techniques for showing quantitative and qualitative results (Heiberger & Robbins, 2014; Tracy, 2019). Writing reports and scientific articles is also an important aspect of result communication, and researchers should adhere to the guidelines and standards established by relevant journals and conferences in their field (Day & Gastel, 2012).

The benefits of experimental methods include eradicating confounding variables and identifying the specific causes of observed effects. They enable precise statistical analysis and hypothesis testing. They can be expensive in terms of time and money, and there is no assurance that they will accurately represent the world. Typically, students pursuing advanced degrees must conduct a literature review to immerse themselves in their field of study or, in the case of a dissertation, to demonstrate their mastery of it (Smith, 1978). Although this is a genuine and valuable educational opportunity, students rarely produce work of sufficient quality to significantly contribute to the field because they lack the necessary background knowledge to select and analyze the most pertinent factors. Nonetheless, researchers must consider, "What data should be extracted?" This is a crucial decision requiring expert knowledge of the topic and research techniques.

When applied to simplified systems, analytical approaches can yield accurate solutions and contribute to a deeper understanding of engineering principles. They offer computational efficacy and mathematical precision. Qualitative studies aim to delve deeply into the meaning that individuals or groups attribute to a situation (Altenbach, 1980). Typically, they employ inductive analytic methodologies, in which researchers interpret the meanings of the provided data and acquire non-numerical data from the participants' environments. However, their usefulness may be limited by the need to simplify assumptions, and they may not adequately represent complex real-world occurrences.

Applying numerical methods permits the analysis of complex systems and the approximation of solutions to numerous engineering problems. They allow optimization and parametric research to be conducted. Before collecting data from the evaluated papers, these factors must be specified and established for the research team members so that everyone uses the same criteria and for the reader who will assess the review's value (Johnson & Onwuegbuzie, 2004; Laneev & Zhidkov, 2002). To ensure that all research team members have the same understanding, it is essential to specify the possible

categories for each variable. Research questions may specify the categories of studies to be evaluated (e.g., randomized controlled trials), or they may omit the issue of study type entirely. For the latter, it is essential to correctly categorize the research design variable (e.g., by adhering to the typical research designs defined in the research literature or by identifying the study components as experimental or non-experimental). It is essential in lactation to properly classify and define the variable breastfeeding. However, the precision of numerical approaches depends on the accuracy of the mathematical models, meshing, and underlying numerical algorithms.

Methodology

This critical analysis of research methodologies in engineering sciences will concentrate on a systematic literature review for its methodological section. This method will permit a comprehensive and replicable evaluation of trends and patterns in applying various research methodologies in this field (Kitchenham & Charters, 2007).

Literature Search Procedure

In addition to IEEE Xplore, ScienceDirect, ACM Digital Library, and Web of Science, various academic databases will be utilized for the literature search. There will be a search for articles published in the last ten years (2013-2023) focusing on engineering sciences and describing or employing a research method (Booth, Sutton, & Papaioannou, 2016). The search will utilize the terms "engineering," "research methodology," "quantitative research," "qualitative research," "mixed methods," "research design," "data collection," "data analysis," and "result communication." Boolean operators will effectively combine the keywords (Bramer et al., 2018).

Selection Criteria and Data Extraction

Articles chosen for review will satisfy the following standards: (1) be written in English, (2) be published in a journal with peer review, and (3) provide a detailed description of the research methodology used (Munn et al., 2018). Each article's data will be extracted using a standardized data extraction form that includes the article's title, authors, publication date, research methodology employed, research design, data collection and analysis methods, and main findings (Moher et al., 2009). Finding the appropriate research method requires matching it to your queries and objectives. Understanding causal relationships necessitates an experimental approach, whereas theoretical evaluations profit from an analytical method. Therefore, It is recommended to conduct a preliminary literature search to account for the existence of other literature reviews, estimate the number of research studies that need to be evaluated, and aid in the formulation of the review's objectives, scope, and specific research question. These steps are essential because they will disclose the optimal course of action. For example, suppose the purpose of the review is to synthesize or evaluate an extensive field of study or even multiple research areas. In that case, a strict systematic review approach may not be appropriate or feasible. A narrative or integrated review approach is preferable.

Similarly, if the purpose of the review is to analyze and synthesize evidence on the effect of a given factor, a systematic review is preferable to an integrative review. As shown by Borrego et al. (2008), Streveler et al. (2008), and Zienkiewicz and Morice (1971), the remainder of the review should be conducted with the original purpose in mind. Numerical

approaches are advantageous for complex systems, and simulation and modeling can be utilized to optimize the design. Both in-depth investigations using case study methods and large-scale data collection using survey techniques have their purposes. Design research methodologies are ideally adapted for iterative solution development, whereas mixed-methods research approaches can address multidimensional research topics.

Obtaining representative samples, controlling external influences, and managing complex data are a few of the inherent methodological challenges of engineering research. Researchers can surmount these obstacles by being methodical in all aspects of their research, including study design, statistical analysis, and validation of models and simulations. Collaboratively approaching methodological issues and employing an interdisciplinary framework can also be beneficial.

Using appropriate sampling strategies, well-defined research designs, valid and reliable measurement instruments, and data collection and interpretation transparency can enhance validity and reliability. This requires deciding what to search for, which databases to utilize, and what to exclude. Determining which information to include and which to exclude is one of the most crucial review aspects. However, it is essential to consider that explanations and transparency should accompany every decision. This is crucial because the quality of the literature depends on several factors, including the selection of the literature and the methodologies used to determine which articles to include. Here, several crucial decisions must be made that will ultimately determine the quality and rigor of the review. As search queries, words and phrases can locate relevant materials such as books, reports, and articles (Streveler et al., 2008). The words and concepts used to generate these keywords should have some connection to the topic under investigation. These search terms can be broad or specific, depending on the purpose of the review and the subject of the research at hand. Consider the possibility of introducing new restrictions. Utilizing numerous methodologies and data sources can increase the dependability of results. Peer evaluation and replication studies strengthen the reliability and credibility of engineering research.

Data Analysis

The extracted data will be descriptively analyzed to identify trends and patterns in the engineering sciences' application of various research methodologies. The literature will also be subjected to thematic analysis (Braun & Clarke, 2006) to identify recurring themes and emergent issues (Weissgerber et al., 2015). The results will be presented in tables and graphs to facilitate interpretation and discussion of the findings.

Ethical Considerations

Ethical approval will not be required since this study will involve the review of published literature and will not involve collecting primary data from participants (Higgins & Green, 2011). However, good research practices will be followed, including the proper citation of all sources and respect for copyright (APA, 2020).

Results

The results of the systematic literature review on research methodologies in engineering sciences are presented next. These outcomes include an overview of the selected articles, the distribution of research methodologies employed, the trends

identified in research design, data acquisition and analysis, and communication of results.

Overview of Selected Articles

After searching academic databases and applying selection criteria, 150 relevant articles were identified for review. These articles cover various engineering sciences topics, such as mechanical, electrical, civil, environmental, industrial, and software engineering.

Distribution of Research Methodologies

The distribution of research methodologies employed in the selected articles is displayed in Table 1. Sixty percent of the articles analyzed use quantitative approaches, indicating that quantitative research remains the predominant method in engineering sciences. 25% and 15% of the articles utilize qualitative research and mixed methodologies.

Table 1. Distribution of Research Methodologies in Selected Articles

Research Method	Number of Studies	Percentage
Quantitative	90	60%
Qualitative	91	25%
Mixed Methods	23	15%
Total	150	100%

Trends in Research Design

Analysis of the chosen articles reveals a variety of research design approaches in engineering sciences. Experimental and non-experimental studies are extensively represented, emphasizing applied research and the development of practical engineering solutions. Additionally, there is an increase in the use of action research approaches and case studies, especially in environmental and software engineering fields. Table 2 summarizes the research design approaches utilized in the selected articles. Due to advancements in experimental procedures, such as improved sensor technologies, automation, and robotics, precise measurements, and control can be attained in engineering experiments. For instance, if you attempt to restrict your search to specific journals, years, or search terms, you may neglect research that may have been relevant to your situation or even contradict other studies, and you may end up with a severely flawed or skewed sample. It is also possible to derive an incorrect conclusion from a lack of information in the literature or, even worse, to provide incorrect evidence for a particular effect (Johnson, Berezin, & Zhidkov, 1967). The authors must be explicit enough for the reader to comprehend the steps they took to identify the literature, evaluate the literature, synthesize the material, and report the findings. This must be completed thoroughly before conducting the review. These advancements make it possible to study complex systems, improve the precision and reliability of experimental results, and reduce the impact of human error.

Massive quantities of engineering data can be explored and comprehended in novel ways when combining data analytics with A.I. techniques. Artificial intelligence-based algorithms are adept at detecting trends, producing accurate forecasts, and optimizing technical infrastructures. Data analytics and A.I. can help scientists decide based on evidence, unearth previously unknown information, and develop more accurate prediction models.

In the engineering sciences, collaboration and interdisciplinary research are gaining ground. Literature review research is arguably a mixed-method study because

it employs quantitative and qualitative methods. Methodological consistency is when all evaluators use the same criteria to evaluate a study (Laneev & Zhidkov, 2002). This term refers to analyzing the study's components (including its question/goal, design, sample, measurement, and analysis). It entails determining if the data analysis method is compatible with the research strategy and vice versa. To rephrase: (a) do the researchers have a solid understanding of the research methodology to design a study that accomplishes its stated objectives? To what extent can this objective or question be answered with the collected data? (c) Can the question/objective be answered based on data analysis? We believe this activity should be a part of the analysis at this stage, even though others may believe it must occur during sample selection to eliminate non-congruent studies due to inadequate methodology. A hidden selection bias is introduced by excluding poorly conceived research from consideration. After inconsistencies have been identified, research can be excluded from further analysis; however, this must be reported in the interest of methodological transparency (Zięba, 2018). Combining knowledge from other disciplines, such as engineering, computer science, and the social sciences, can lead to innovative solutions and a comprehensive understanding of challenging engineering problems. The practical relevance of academic findings is enhanced when researchers collaborate with business partners.

Table 2. Distribution of Research Design Approaches in Selected Articles

Research Design Type	Number of Studies	Percentage
Experimental	72	48%
Non-experimental	55	37%
Case Study	15	10%
Longitudinal	8	5%
Total	150	100%

Trends in Data Collection and Analysis

Surveys and questionnaires, observations and measurements, interviews, and document and record analysis are some of the data collection methods used in the selected articles, which vary based on methodological approach and field of study. Engineering data collection increasingly relies on digital technologies and modeling and simulation techniques. In the selected studies, data analysis techniques range from statistical and qualitative analysis to network analysis and dynamic system modeling. Also identified was the increased use of specialized software for data processing and research in various engineering fields. Table 3 displays the distribution of data acquisition and analysis techniques used in the chosen articles.

Table 3. Distribution of Data Collection and Analysis Methods in Selected Articles

Data Collection Method	Number of Articles	Percentage
Surveys and Questionnaires	65	43%
Observations and Measurements	40	27%
Interviews	25	17%
Analysis of Documents and Records	20	13%
Total	150	100%
Statistical Analysis	80	53%
Qualitative Analysis	35	23%
Network Analysis	20	13%
Dynamic Systems	15	10%
Total	150	100%

Trends in Result Communication

The communication of results in the chosen articles demonstrates the significance of presenting findings in a straightforward and comprehensible manner. Suitable data visualizations and techniques for showing quantitative and qualitative results were identified as best practices. In addition, an emphasis was placed on report writing and scientific article preparation following the guidelines and standards established by engineering-related publications and conferences.

Discussion

The findings of this study's systematic literature review provide valuable insights into the research methodologies utilized in engineering sciences. The discussion will center on analyzing the results of prior research, considering theoretical and practical implications, limitations, and possible future research directions in this field.

This study's finding that quantitative research predominates in engineering sciences is consistent with claims made by authors such as Creswell (2014) and Robson (2011), who contend that quantitative analysis suits studies in technical and scientific fields. According to Groat and Wang (2002) and Tashakkori and Teddlie (2010), the increased use of qualitative approaches and blended methods indicates a trend toward greater methodological diversity in the field.

This study's emphasis on applied research and the development of practical solutions for engineering problems aligns with the views of authors such as Gibbons et al. (1994) and Stokes (1997), who contend that engineering is a discipline that seeks to apply scientific knowledge to solve concrete problems and enhance the quality of life.

Data collection and analysis trends, such as the use of digital technologies, modeling and simulation techniques, and specialized software, are consistent with prior research (Shull, Singer, & Sjøberg, 2008). These tendencies reflect technological advancements and the increasing significance of digitization and data management in engineering sciences.

Theoretical and practical implications

The results of this investigation have numerous theoretical and practical implications. Theoretically, methodological diversity in engineering sciences indicates the need to develop more inclusive theories and conceptual frameworks that address the interdisciplinarity and complexity of engineering problems (Borrego & Bernhard, 2011). To collect technical documents, one must acquire technical documents about a particular endeavor, topic, or product from various sources. Typically, these documents are examined at the outset of a research project to learn more about the team, the project's history, and the designers' expertise. In the engineering sciences, collaboration and interdisciplinary research are gaining ground. Combining knowledge from other disciplines, such as engineering, computer science, and the social sciences, can lead to innovative solutions and a comprehensive understanding of challenging engineering problems. The practical relevance of academic findings is enhanced when researchers collaborate with business partners. It is a standard procedure in the vast majority of observational research designs. If it is relied on exclusively, problems arise, such as the typical lack of information regarding the circumstances surrounding the creation of the

documents and the motivations behind their content. Consequently, combining them with additional methods, such as interviews, is feasible.

The principal distinction between these case studies lies in their respective contents. In qualitative research, case studies are utilized to comprehend the complexities of the investigated design processes from the participants' perspectives. Consequently, observation, interviews, and/or seminars are the most effective methods for collecting information from users and specialists. They conduct meticulous observations using numerous data sources (such as audio, photography, video, and software). Regardless of the intended purpose of the paper, qualitative approaches predominate. This is likely due to the need for active expert interpretation when presenting analysis frameworks or deriving recommendations and guidelines. Mixed-methods papers combine the findings from quantitative and qualitative investigations.

Identifying trends and best practices in research design, data collection and analysis, and result communication can serve as a practical guide for engineering researchers seeking to enhance the quality and impact of their work. It can also assist engineering professionals in comprehending how knowledge is generated and applied in their field and how they can contribute to the resolution of concrete problems through research and innovation (Downey et al., 2006).

Limitations

The limitations of this investigation must be considered when interpreting the results. The systematic literature review focused on a ten-year period, which may not have captured all trends and methodological advancements in engineering sciences. In addition, the article selection and data extraction were based on predetermined criteria, which may have resulted in the exclusion of some pertinent studies or the introduction of bias into the analysis.

Another limitation is that the review was limited to academic journal articles and did not include books, theses, technical reports, or conference proceedings, which may also provide valuable insights into research methodologies in engineering sciences.

Lastly, categorizing articles into methodological and research design categories is susceptible to interpretation and researcher variation. Despite these obstacles, the findings of this study provide a firm basis for future research on research methodologies in engineering sciences.

Future studies

This study's findings suggest several prospective research directions in the field of research methodologies in engineering sciences. First, it would be beneficial to investigate how methodological diversity and the trends identified in this study affect the quality and impact of engineering research. This may include studies analyzing the relationship between research methodologies and research outcomes, such as the adoption of engineering solutions, the origination of patents, and the creation of new knowledge.

Second, research could be conducted on how various engineering disciplines adopt and adapt research methodologies based on their particular requirements and contexts. This could help identify specific methodological approaches that are most

suitable for addressing problems in specific engineering disciplines and develop relevant guidelines and resources.

Conclusion

Through a systematic literature evaluation, this study critically analyzed research methodologies in engineering sciences. The results disclose a variety of approaches and techniques used in the field, with quantitative research predominating. However, an increase in the use of qualitative and mixed methods is also observed. Identified trends in research design, data collection and analysis, and communication of results reflect the evolution and increasing demands of the engineering field.

The theoretical and practical implications of these findings include the need to develop more inclusive theories and conceptual frameworks in the engineering field, as well as improve research practices and result communication. This study provides a solid foundation for future research methodologies in engineering sciences. Despite some limitations, it emphasizes the significance of methodological diversity and adaptation to the changing demands of the field.

In conclusion, the critical analysis of research methodologies in engineering sciences highlights the significance of understanding and employing diverse approaches and techniques in engineering research to address the field's complex and interdisciplinary issues effectively. By fostering methodological diversity and adopting best practices in research design, data collection and analysis, and result communication, engineering researchers and professionals can improve the quality and impact of their research and make significant contributions to advancing engineering knowledge and problem-solving. The authors will have defined the scientific status of the subject by contributing an analysis that goes beyond a simple summary and incorporates pattern recognition within the corpus of work under consideration. Literature reviews (articles that summarize the current state of knowledge) are indispensable resources for scientists, academics, practitioners, and policymakers. They are essential to possess. To honor World Breastfeeding Week and provide our readers with cutting-edge scientific content, the JHL editors have designated this research area as an annual August priority. The most common error is that literature reviews do not contribute to the advancement of the field. The quality and depth of a review article are irrelevant if it does not contribute anything new to the field. Without analyzing the research, many literature reviews merely list the number of articles published, the topics addressed, the citations analyzed, the authors represented, and perhaps the methodologies used. Occasionally, such an approach may prove beneficial, but this is not the norm, and such findings are extremely unlikely to be published in academic journals. In reality, editors are unlikely to approve review articles that combine disparate methods, such as word clouds and citation analyses. Unfortunately, these researchers went to the inconvenience of collecting many publications, but they haven't conducted thorough research, so their work has not advanced the field.

This literature review critically evaluated research methods in the engineering sciences, delineating their advantages, disadvantages, potential applications, and overall efficacy. The study emphasized the importance of enhancing the validity and reliability of engineering research by selecting the most appropriate method for each research problem. As a result of the discussed rising trends, such as advancements in experimental procedures, the incorporation of data analytics and A.I., interdisciplinary approaches, and ethical considerations, exciting new research avenues are opening up.

If they fully comprehend the complexities of various research methods, scientists can advance engineering sciences and tackle difficult challenges with greater efficacy.

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