Operational Research in Engineering Sciences: Theory and Applications
Vol. 6, Issue 1, 2023, pp. 274-292
ISSN: 2620-1607
eISSN: 2620-1747
DOI: https://doi.org/10.31181/oresta/0601128

CURRENT TRENDS IN RESEARCH METHODS FOR ENGINEERING: A CONTEMPORARY STUDY

Miguel Ángel Medina Romero[1], Wilson Wily Sardon Quispe[2], Wilson Cruz-Mamani[3*], Mercedes Alejandrina Collazos Alarcón[4], Juan Carlos Zapata Ancajima[5], Magaly Quiñones-Negrete[6], Julián Gutiérrez Aparco[7], Jose Alberto Aguilar Franco[8], Fredy Alberto Hernández Hernández[9], Isaac Merino Quispe[10]

[1] Universidad Michoacana de San Nicolás de Hidalgo.
[2] Universidad Nacional Amazónica de Madre de Dios.
[3] Universidad Peruana Unión Juliaca, Peru.
[4] Universidad Tecnológica del Peru.
[5] Universidad Nacional de Piura.
[6] Universidad Católica Los Ángeles de Chimbote.
[7] Universidad Nacional José María Arguedas.
[8] Universidad Católica San Pablo de Arequipa.
[9] Universidad Nacional San Luis Gonzaga de Ica
[10] Universidad Nacional Jose Maria Arguedas.

Received: 01 January 2023
Accepted: 19 March 2023
First Online: 27 April 2023

Research Paper

Abstract: *This study is devoted to reviewing and analyzing current trends in engineering research methods, concentrating on modeling and simulation, machine learning, artificial intelligence, and complex systems engineering. Selected and analyzed academic articles published within the last five years were used to create a critical analysis. Despite the associated challenges, such as the need for new competencies and resources, the results indicated that these emergent methods significantly impact the engineering field. However, significant voids were also identified, including the inability to solve engineering problems innovatively and efficiently. This study concludes by emphasizing the need for additional in-depth research into these trends and their effects on various engineering disciplines.*

Keywords: *Research Methods in Engineering, Modeling and Simulation, Machine Learning, Artificial Intelligence, Complex Systems Engineering.*

---

*Corresponding author: wilson.cruz@upeu.edu.pe, (W. C. Mamani)
miguel.medina.romero@umich.mx, (M. A. M. Romero), wsardon@unamad.edu.pe, (W. W. S. Quispe), c24133@utp.edu.pe, (M. A. C. Alarcón), jzapataa@unp.edu.pe, (J. C. Z. Ancajima), mquinonen@uladech.edu.pe, (M. Q. Negrete), jugutierrez@unajma.edu.pe, (J. G. Aparco), jaaguilar@ucsp.edu.pe, (J. A. A. Franco), fredyhernandez1602@gmail.com, (F. A. H. Hernández), merinoq501@gmail.com, (I. M. Merino)

Introduction

Engineering has developed into an indispensable instrument for solving complex problems and enhancing the quality of human existence. Escudero-Mancebo et al. (2023) note that modern engineering is a sophisticated and specialized field that requires innovative research methods to satisfy the demand for efficient and sustainable solutions. This demand has stimulated the development of the most recent trends in engineering research methods, such as modeling and simulation, machine learning and artificial intelligence, and complex systems engineering (Abi Akle, Yannou, & Minel, 2019; Khaleel, Ahmed, & Alsharif, 2023). In the past, engineering research centered on empirical and experimental methods (Dźwigoł, 2019), which sought to solve practical issues (Ibrahim et al., 2022). These approaches' tangible and action-oriented nature, which offered solutions based on actual observations and direct experimentation, distinguished them. However, a significant transition has been toward incorporating theoretical and computational techniques driven by technological and data science advancements (Darmawansah et al., 2023).

Data science has been instrumental in this transformation. The capacity to collect, process, and analyze vast quantities of data has enabled engineers to create more complex models and conduct more precise analyses (Adams et al., 2011; Yig, 2022). This has led to a deeper integration of data science into engineering research, with an increasing emphasis on machine learning, artificial intelligence, and other advanced computational techniques (Chowdhury & Schoen, 2020; Sachini et al., 2022). Simultaneously, the complexity of engineering systems has prompted a shift toward more systemic and holistic research methods (Ho & Goethals, 2022). Complex systems engineering, rooted in systems theory and mathematical modeling, has emerged as a leading engineering research field. These modifications represent a major paradigm shift in engineering research (Glänzel & Schubert, 2003). Despite the continued importance of empirical and experimental methods, theoretical and computational techniques are anticipated to play an increasingly important role in the future (Lê & Schmid, 2022). This shift presents both challenges and opportunities for engineering researchers, as it necessitates the development of new skills and competencies (Klavans & Boyack, 2017) while simultaneously providing the opportunity to approach engineering problems from new perspectives and develop more innovative and efficient solutions (Okamura, 2022).

Changes in engineering research methods have consequences for engineering education (Willer et al., 2011). As research methods evolve, so do the required skills and competencies for future engineers. This highlights the need to reform engineering curricula to include and provide a firmer foundation in data science, computational techniques, and complex systems. Other significant trends in engineering research include simulation and computational modeling (Van den Berghe et al., 2019). These techniques, made possible by advances in information technology and high-performance computation, enable engineers to investigate and predict the behavior of complex systems more efficiently and precisely than with conventional experimental methods (Conde et al., 2021). In addition, the revolution in artificial intelligence and machine learning has substantially affected engineering research (Nugroho, Anna, & Ismail, 2023). These technologies are used to automate and optimize design and manufacturing processes and to analyze large volumes of data generated by engineering systems (Okunlaya, Syed Abdullah, & Alias, 2022; Sofian, Yunus, & Ahmad, 2022).

The increasing use of simulation, computational modeling, AI, and machine learning in engineering research presents challenges, such as the need for substantial computational resources and a solid grasp of mathematics and computer theory (Çetin & Demircan, 2020; Ciston, 2019; Shin & Xu, 2017). In addition, if their limitations and underlying assumptions are misunderstood, the results obtained through these techniques can be misinterpreted or misapplied (Tempelaar, Rienties, & Nguyen, 2020). On the other hand, interdisciplinary and collaborative approaches are becoming increasingly popular in engineering research (Muller, 2013; Thiel, 2014). Current engineering challenges are frequently so complex that they transcend traditional disciplines, necessitating the integration of skills and knowledge from multiple disciplines (Alarcón & Anwar, 2022; Ali, Langen, & Falk, 2022). This has resulted in novel subdisciplines, such as bioengineering and environmental engineering, combining life science and social science principles.

Collaboration has become the norm in engineering research, with research teams frequently consisting of engineers from various specializations and scientists from other fields (Finelli, 2018). Collaboration also transcends institutional and geographical boundaries, combining a vast array of skills, experiences, and perspectives worldwide (Mejia et al., 2018). Creswell (2021) notes that the growing significance of interdisciplinarity and collaboration in engineering research has significant implications for engineering education. Engineering education must adapt to prepare engineers to work in interdisciplinary and collaborative environments. This includes the development of communication and collaboration skills, as well as a deeper understanding of non-engineering disciplines. While interdisciplinarity and collaboration provide excellent opportunities to advance engineering research, they also present obstacles. These include challenges in inter-disciplinary communication, cultural and organizational conflicts, and managing diverse research teams (Wohlin & Runeson, 2021). However, with effective leadership and management, these obstacles can be surmounted to reap the benefits of interdisciplinary and collaborative research.

Engineering is constantly evolving, driven by technological advances and the growing complexity of humanity's problems (Goecks et al., 2021). Engineering research methods must also keep pace with these changes and challenges. Historically, engineering research focused on empirical and experimental methods; however, there has been a significant transition toward incorporating theoretical and computational methods (Kamiri & Mariga, 2021). Modeling and simulation, machine learning and artificial intelligence, and complex systems engineering are the most recent trends in engineering research, and they all represent a paradigm shift. However, a lacuna has been identified in the existing literature. While numerous studies have been conducted on individual engineering research methods, there is a lack of a comprehensive and up-to-date analysis encompassing the spectrum of current trends in these methods (Gyory, Cagan, & Kotovsky, 2019).

Consequently, there is a growing need for a systematic review of current research methods in the field of engineering that can provide a comprehensive and detailed overview of these trends and how they are influencing the field of engineering. In addition, these new techniques and developments present both obstacles and opportunities for engineers (Han, Forbes, & Schaefer, 2021). On the one hand, employing these techniques necessitates the acquisition of new skills and competencies, as well as the deployment of substantial computational resources. On the other hand, they provide the opportunity to approach engineering problems from new angles and to develop more creative and effective solutions. Nonetheless, a comprehensive analysis of these obstacles and opportunities has not yet been conducted.

Therefore, the primary objective of this study is to provide a comprehensive and current review of current trends in engineering research methods and to analyze how these trends are transforming the engineering field (Renzi, Leali, & Di Angelo, 2017). This will require a review and synthesis of the existing literature on engineering research methods, such as modeling and simulation, machine learning and artificial intelligence, and complex systems engineering. In addition, this study aims to examine the obstacles and opportunities associated with adopting these new research methodologies. This will include a detailed discussion of the skills and competencies required for these methods, the resources required, and the innovative and efficient ways these methods can be used to solve engineering problems.

Literature Review

Fundamentally, engineering is about solving problems and enhancing the quality of human existence. Engineers have historically utilized a variety of empirical and experimental research methodologies to accomplish this (Cooper, 2019). Empirical research is characterized by its tangible and action-oriented nature, based on observation and direct experimentation. In contrast, experimental approaches investigate relationships between variables through controlled experiments (Creswell, 2003; Kitchenham et al., 2009). However, the literature indicates that a significant shift in engineering research methodologies is occurring. Specifically, technological and data science advancements have led to greater incorporation of theoretical and computational techniques in engineering research (Khaleel et al., 2023). These themes represent a paradigm shift in engineering research: data science, modeling and simulation, machine learning and artificial intelligence, and complex systems engineering.

Data Science

Data science combines statistical, mathematical, and computational methods to analyze and extract knowledge from data. Data science is an umbrella term for systematic data acquisition and analysis, hypothesis testing, and forecasting. Thus, the discipline encompasses numerous facets of the information technologies used for data acquisition, fusion, mining, forecasting, and decision-making" (Dhar, 2013). In engineering, data science is used to create more complex models and conduct more precise analyses on massive amounts of data to make sense of it and present the insights and findings in a way that aids decision-making. The incorporation of data science into engineering has resulted in the development of cutting-edge technologies such as machine learning, artificial intelligence, and other advanced computational techniques that enable engineers to complete their tasks in an automated manner and make decisions that are supported by validated data sources (Chowdhury & Schoen, 2020; Sachini et al., 2022). Machine learning methods, a subfield of artificial intelligence that focuses on developing systems that can learn from data, are especially pertinent in this context (Van der Aalst, 2014). These methods allow engineers to automate and optimize design and production processes and analyze large volumes of data generated by engineering systems (Chopra & Arora, 2022). Today, data in all disciplines are readily available and accessible due to the rapid pace of digitalization and the presence of open-access sources. The events' resulting experiences and observations are recorded, allowing for the accumulation of massive amounts of data. This information contributes to forming patterns and associations that assist in comprehending and analyzing the situation at hand. By feeding large amounts of data and its patterns to a computerized system, machine learning occurs, which is essentially associated with "obtaining a computed model of complex non-linear relationships or complex patterns within data (usually beyond human capability and established physics to define)" (Dimiduk, Holm, & Niezgoda, 2018). Machine learning is a subset of artificial intelligence defined as "the framework for making machine-based decisions and actions utilizing ML tools and analyses" (Dimiduk et al., 2018). Artificial intelligence aims to make computers so efficient that they can perform tasks as efficiently as humans, if not more efficiently. "The term 'AI' is used when a machine simulates functions that humans associate with other human minds, such as learning and problem solving" In this manner, humans can focus on other strategic tasks, such as decision making, while AI technology takes care of mundane, repetitive tasks. Machine learning entails feeding and discovering patterns in data to accomplish AI objectives. "Commonly, three types of learning are recognized:'supervised' learning, in which the system learns from known data; 'unsupervised' learning, in which the unassisted system finds patterns in data; and reinforcement learning, in which the system is programmed to make educated guesses at solutions and is rewarded in some way for correct answers, but is given no feedback about incorrect answers (Dimiduk et al., 2018; Thai, 2022). As a result of the development of these technologies, engineering has not lagged. In the past decade, engineering practice and research have undergone a significant paradigm shift (Glänzel & Schubert, 2003). Due to the limited quantity and expense of available data, data science, machine learning, and artificial intelligence were not previously widely utilized in engineering. Today, however, data is widely accessible and available at a very low cost (sometimes at no cost), enabling the enormous integration and incorporation of these technologies in the engineering field. Nonetheless, this paradigm shift presents both challenges and opportunities for engineering practitioners and researchers, necessitating the development of new skills and competencies (Klavans & Boyack, 2017) while simultaneously providing the opportunity to approach engineering problems from new perspectives and develop more innovative and efficient solutions (Okamura, 2022). Developments and advancements in engineering research also have impacts on the academic field of engineering (Willer et al., 2011), necessitating transformation and reformation of engineering curricula to incorporate the use of the latest technologies so that the next generation of engineers will be equipped with the skills and competencies necessary to deal with the latest advancements in the field and to make efficient use of the resources (Conde et al., 2009). Alongside the adoption of modern digital technologies in the practice of engineering, it is crucial to concentrate on developing skills through curriculum development and training to meet the changing demands of the present.

Complex Systems Engineering

Additionally, sophisticated systems engineering is receiving increased focus. Complex systems consist of many interconnected parts whose global behavior cannot be readily predicted from the behavior of the individual components (Herzog et al., 2022). Complex systems engineering employs systems theory and mathematical modeling to analyze complex systems and develop engineering solutions (Beale et al., 2022). Engineers may fully understand individual systems in a large network of systems, but when these systems are interconnected, they become quite complex and often behave in ways that are difficult to fully comprehend (also known as the emergent behavior of complex systems). As patterns can only be observed across space and time, these dynamic behaviors of complex systems can be analyzed spatially-temporally. "In conventional systems engineering, the objective is to design a closed, predictable system. The situation is somewhat different for natural systems, which are open systems and replete with irreducible macro-level emergent behaviors at the micro-level. This novel irreducible macro-behavior adds to the complexity of adaptive systems, specifically when it becomes causal at the micro-level, resulting in a fundamental shift in the behaviors at multiple system levels. To adapt to a new environment, the system created novel multi-level interactions and positive and negative feedback loops" (Tolk, Diallo, & Mittal, 2018). Sheard and Mostashari (2009) offer a thorough definition of complex systems. They suggest that complex systems comprise numerous autonomous units that serve as the system's building materials. Individual units are heterogeneous, i.e., they have different fundamental characteristics, and the system's limits or boundaries are not defined. In addition, complex systems exhibit emergent behaviors at the macro level that result from the interdependence of individual entities at the micro level. Understanding the individual units is insufficient to comprehend the structure and behavior of the entire system; it is necessary to comprehend the interrelationships and interactions of all the individual units to understand the complex system as a whole. There may be groupings and hierarchy in the individual units' interconnectedness, but no central authority controls the system. The behavior is non-linear, i.e., it lacks equilibrium and is primarily chaotic (Diallo, Mittal, & Tolk, 2018). These complex systems continue to evolve and adapt to an ever-changing environment, increasing their complexity.

To summarize, complex systems have the following characteristics: autonomous interrelated parts, undefined boundaries, self-organization, input and output of energies, emergent macro-level behavior, non-linear behavior, absence of central authority, continuous adaptation to the environment, increased complexity with time and evolution, and changing of elements due to pressures from neighboring components. There has been increased research on complex systems, such as complexity, non-linear dynamics, and chaos theory studies. First, emergence, or the study of individual units' interdependence, the macro system's dependence on the micro-level individual components, and the specialization of individual units. While one may not understand the entire complex system through its components, it is still crucial to know how all the individual units function and how changes in one unit affect the others, i.e., interrelationships, to comprehend the system's fundamental components. Second, mathematical modeling can be used to study pattern formation. Third, multiple (meta-) stable states, or the study of minor shifts that can aid the system's recovery and radical shifts that can completely alter its characteristics. Fourth, a description of multiscale, or the study of micro scales that have the potential to influence the behavior of larger scales. Fifth, comprehending the magnitude and level of complexity. Sixth, the comprehension of the system's behavior through the response function. Seventh, identifying contrasting behaviors, such as order and disorder, randomness, and predictability (Sheard, 2006).

Stability, mechanism, linearity, control, Newtonian laws, and simplicity were the traditional objectives of systems engineering. Everything was predictable and organized, and everyone was aware of their duties. Nevertheless, complex systems engineering "focuses primarily on identifying existing complex systems and their ongoing evolutionary trends, and then influencing them so that the system evolves to produce more desired results" (Sheard & Mostashari, 2009). The complex system is characterized by complexity and chaos, including adaptation, agility, prioritization, capability, flexibility, variety, instability, many distinct domains, reactions, and diminished control. Complex systems in the actual world are not completely chaotic. Some aspects of the ordered systems and complex systems overlap.

Interdisciplinary and Collaborative Approaches

Engineers have different duties and responsibilities in today's interconnected world than in the past. Engineers must possess dynamic abilities to confront dynamic challenges. Now, engineers are needed who are socially connected and who are not only experts in their field but also can work across disciplines (Van den Beemt et al., 2020). Future engineers must be able to access, comprehend, evaluate, synthesize, and employ perspectives and knowledge from other fields. These competencies enable engineers to have dynamic views and to consider various environmental and social factors when addressing modern issues (Lattuca, Knight, & Bergom, 2013). There has also been a shift toward more interdisciplinary and collaborative research approaches (Johnston, Burleigh, & Wilson, 2020), which parallels these changes in engineering. a Changes in engineering research methods have consequences for engineering education (Alarcón & Anwar, 2022; Ali et al., 2022). This trend has resulted in new subdisciplines, such as bioengineering and environmental engineering, integrating life science and social science principles. In addition, the literature emphasizes the importance of collaboration in engineering research. According to (Meyer et al., 2022), collaborative work has become the norm in engineering research, with research teams frequently consisting of engineers from various specialties and scientists from other fields (Finelli, 2018). The inter-disciplinary collaborations are not limited by geography or institution; rather, they involve the integration of the skills, expertise, perceptions, experiences, and competencies of people from all over the world, thereby forming a team of intellectuals and think tanks capable of producing high-quality reforms and decisions (Mejia et al., 2018). "Interdisciplinary research processes entail negotiating how knowledge is pursued and valued and can lead to new conceptual frames, methodologies, and modes of teaching and communication. Potential benefits of interdisciplinary research include innovative contributions to disciplinary knowledge, professional and personal development of participants, expanded horizons from which to approach research problems, and less hierarchical, more collegially interdependent relationships between faculty and student researchers" (McNair, Davitt, & Batten, 2015).

Creswell (2021) notes that the growing significance of interdisciplinarity and collaboration in engineering research has significant implications for engineering education. Engineering education must adapt to prepare engineers to work in interdisciplinary and collaborative environments. This includes the development of communication and collaboration skills, as well as a deeper understanding of non-engineering disciplines. To be considered inter-disciplinary, multiple disciplines must have a certain level of inter-relationship and integration (Huutoniemi et al., 2010), as "interdisciplinarity requires methodological or conceptual synthesis with the aim of deepening knowledge and skills" (English, 2016). "In interdisciplinary teams, individuals learn from the perspectives of others and produce work through an integrative process that would not be possible in a single-disciplinary setting" (McNair et al., 2011). Despite these significant modifications to engineering research methodologies, several obstacles have been identified. These include the need for substantial computational resources, in-depth knowledge of mathematics and computer theory, and the possibility that results obtained through advanced computational techniques may be misinterpreted or utilized inappropriately. In addition, interdisciplinarity and collaboration present obstacles, such as difficulties in inter-disciplinary communication, cultural and organizational conflicts, and challenges in managing disparate research teams (Wohlin & Runeson, 2021). Literature suggests that engineering research methods are undergoing a significant shift, with a growing emphasis on theoretical and computational techniques and a recognition of the significance of interdisciplinarity and collaboration. However, this transition also presents challenges, which require additional research to comprehend and address.

Methodology

Methodological Design

The purpose of this conceptual paper was to produce a critical review of past engineering literature to analyze emergent trends in the engineering field. This method (i.e., critical review) assisted in presenting a comprehensive overview of current trends in engineering research methods and identifying the opportunities and challenges associated with the most recent developments in the field (Saldaña, 2021). This methodology also allowed for a thorough and rigorous subject analysis (Clark et al., 2020).

Data Collection

The academic literature available in relevant databases such as IEEE Xplore, JSTOR, Web of Science, Google Scholar, and SciELO, among others, was this study's primary data source. The study focused on research articles, literature evaluations, conference reports, and doctoral dissertations that discuss engineering research methods. The search was conducted systematically using pertinent keywords and specific inclusion and exclusion criteria.

Literature Selection Criteria

It was ensured that the studies and articles selected for the review must meet the following criteria (Blessing & Chakrabarti, 2009):

1. They must discuss research methods in engineering.
2. They must have been published within the last five years to ensure current data.
3. They must be available in full text.
4. They must come from reliable academic or professional sources.
5. They must be written in English or Spanish.

Studies that did not meet these criteria were excluded.

Data Analysis

Data analysis was conducted through a critical content analysis of the available past engineering literature. The data extracted from the literature were coded and categorized to facilitate the interpretation of identified patterns and trends. To address the challenges and opportunities associated with the adoption of these novel research methods, a thematic framework was developed, enabling the identification of common and emerging themes (Redstrom, 2017).

Ethical Considerations

This investigation was committed to adhering to academic research's ethical standards. All cited works were duly attributed to their respective authors, and copyright was respected. In addition, efforts were made to utilize open-access or legitimately accessible sources. The evaluation was conducted with the uttermost regard for the integrity of the works consulted and their authors.

Results

The results of this study, based on the literature review of research methods in engineering, are presented below:

Modeling and Simulation

In engineering, modeling, and simulation have acquired significant importance. These techniques enable engineers to forecast the behavior of an engineering system before its actual implementation, saving time and resources.

Table 1.1: Trends in modeling and simulation

Research Method	Main Trends	Source
Modeling and Simulation	1. Utilization of advanced modeling and simulation software 2. Integration of simulation with artificial intelligence to enhance accuracy. 3. Use of simulations for real-time decision-making	(Fujimoto et al., 2017), (Sinha et al., 2001), (Sokolowski & Banks, 2011).

Machine Learning and Artificial Intelligence

Machine learning (ML) and artificial intelligence (AI) are two other engineering research methodologies that have grown substantially in recent years. Using digital technologies, these methods enable the automation of complex engineering duties and the analysis of large volumes of data.

Table 2.1: Trends in Machine Learning and Artificial Intelligence

Research Method	Main Trends	Source

Machine Learning and Artificial Intelligence	1. Utilization of ML/AI for predictive analysis 2. Application of ML/AI for automation of engineering tasks 3. Integration of ML/AI with other technologies, such as IoT and cloud computing	(Chowdhury & Schoen, 2020), (Dimiduk et al., 2018), (Kamiri & Mariga, 2021), (Khaleel et al., 2023).

Complex Systems Engineering

Complex systems engineering is a research methodology concerned with designing and managing large-scale and multidisciplinary engineering systems. Due to the growing complexity of engineering systems, this research approach is gaining significance.

Table 3.1: Trends in Complex Systems Engineering

Research Method	Main Trends	Source
Complex Systems Engineering	1. Utilization of advanced modeling and simulation techniques 2. Integration of different engineering disciplines in system design 3. Use of emerging technologies, such as ML/AI, to manage complexity	(Sheard & Mostashari, 2009), (Tolk et al., 2018), (Diallo et al., 2018)

Changes in the Field of Engineering

Lastly, these trends in engineering research methods are driving significant changes in the engineering discipline. These changes include increased demand for specialized skills and competencies, a shift toward integrating various engineering disciplines, and a growing reliance on emergent technologies.

Table 4.1: Changes in the Field of Engineering

Changes	Description	Source
Skills and Competencies	The adoption of new research methods requires specialized skills and competencies.	(Wohlin & Runeson, 2021).
Interdisciplinary Integration	There is a trend toward integrating different disciplines in engineering systems design.	(Van den Beemt et al., 2020), (Ursić et al., 2022), (Meyer et al., 2022)
Dependency on Emerging Technologies	The engineering field increasingly depends on emerging technologies like ML/AI and IoT.	(Dimiduk et al., 2018), (Kamiri & Mariga, 2021)

In conclusion, this study demonstrates that engineering research methods are swiftly evolving and are driving significant changes in the field. Adopting these new research methods presents significant opportunities for innovation and efficacy in engineering and challenges, such as the need to develop specialized skills and competencies.

The following are the findings regarding the challenges and opportunities related to the adoption of novel engineering research methods:

Challenges in the Adoption of New Research Methods

1.1 Modeling and Simulation

Adopting modeling and simulation as research methodologies in engineering presents specific difficulties. A significant obstacle is the requirement for specialized skills and competencies to design and implement effective simulation models. Furthermore, modeling and simulation require access to expensive, high-performance technology and specialized software.

Table 1.1: Challenges in the Adoption of Modeling and Simulation

Challenge	Details	Source
Skills and Competencies	Requires deep mathematical and computational knowledge.	(Fujimoto et al., 2017)
Resources	The necessary hardware and software can be costly.	(Sokolowski & Banks, 2011),(Fujimoto et al., 2017)
Time	Developing and testing simulation models can be a time-intensive process.	(Fujimoto et al., 2017), (Sinha et al., 2001)

1.2 Machine Learning and Artificial Intelligence

Additionally, the incorporation of AI/ML presents obstacles. AI/ML adoption, like modeling and simulation, requires specialized skills and competencies. To train ML models, large quantities of high-quality data are also needed.

Table 1.2: Challenges in the Adoption of AI/ML

Challenge	Details	Source
Skills and Competencies	Requires competencies in programming, statistics, and ML algorithms.	(Klavans & Boyack, 2017)
Data	Requires access to large volumes of high-quality data for model training.	(Chowdhury & Schoen, 2020)
Transparency	ML models can be "black boxes," and their results can be difficult to interpret.	(Thai, 2022)

1.3 Complex Systems Engineering

In addition, complex systems engineering presents unique challenges. Given the often interdisciplinary nature of these systems, this approach necessitates a comprehensive comprehension of how the various components of a system interact with one another.

Table 1.3: Challenges in the Adoption of Complex Systems Engineering

Challenge	Details	Source

Skills and Competencies	Requires knowledge of different disciplines and how they interact.	(Tolk et al., 2018)
Complexity	The design and management of complex systems can be a challenging process.	(Beale et al., 2022)
Interdependence	Changes in one part of the system can have unforeseen.	(Herzog et al., 2022)

Opportunities in the Adoption of New Research Methods

Despite these challenges, adopting these new research methods also presents significant opportunities. These opportunities are summarized in the following table:

Table 2.1: Opportunities in the Adoption of New Research Methods

Research Method	Opportunities	Source
Modeling and Simulation	Allows for predicting the behavior of engineering systems before their actual implementation.	(Fujimoto et al., 2017)
Machine Learning and Artificial Intelligence	Enables the automation of complex engineering tasks and analysis of large volumes of data.	(Dimiduk et al., 2018), (Kamiri & Mariga, 2021), (Khaleel et al., 2023).
Complex Systems Engineering	Enables the design and management of large-scale and interdisciplinary engineering systems.	(Tolk et al., 2018), (Diallo et al., 2018)

These findings demonstrate that, although adopting new research methods in engineering presents challenges, it also provides significant opportunities for innovation and efficiency in engineering.

Discussion

The discussion is a crucial component of any research study because it provides a detailed analysis of its findings, correlates them to existing literature, and identifies potential areas for future research. In the context of this study, the discussion will center on contrasting the obtained results to the initial objectives stated in the introduction and the theoretical and practical implications of the results. In the opening of the study, it was noted that the primary goal was to provide a comprehensive and up-to-date review of current trends in engineering research methods and to analyze how these trends are influencing the field of engineering (Okunlaya et al., 2022; Renzi et al., 2017). This review would include engineering research methods such as modeling and simulation, machine learning and artificial intelligence, and complex systems engineering (Ali et al., 2022; Shin & Xu, 2017; Sofian et al., 2022; Yig, 2022). The results of the literature review provide support for this objective.

Modeling and simulation, machine learning and artificial intelligence, and complex systems engineering have been identified as the most influential research methods in modern engineering (Herzog et al., 2022; Ho & Goethals, 2022; Khaleel et al., 2023). These methods have demonstrated their efficacy in enhancing the efficiency and effectiveness of engineering. Modeling and simulation enable the prediction of engineering system behavior before implementation. Automating complex engineering duties and analyzing vast amounts of data is made possible by machine learning and artificial intelligence. Complex systems engineering allows for designing and managing large-scale, multidisciplinary engineering systems. However, despite these advantages, applying these methodologies in the engineering field is not without obstacles. Engineers must acquire new skills and competencies to utilize these techniques effectively. In addition, employing these methods may necessitate substantial resources, such as cost, time, high-performance software and hardware, and access to vast data (Lê & Schmid, 2022; Muller, 2013). In addition, the design and management of complex systems can be challenging due to a lack of comprehension of the systems' complexities and interdependencies. In addition, this study identifies the significance of interdisciplinary collaboration in engineering, as this discipline is now intricately intertwined with other fields, such as IT, society, governance, environmental policies, and management.

Consequently, there have been increasing collaborations in practice and research, allowing for a better comprehension of the big picture. Therefore, while the emergence of cutting-edge technologies in engineering provides a plethora of benefits and opportunities for engineers, they also present several challenges that must be overcome to make optimal, efficient, and effective use of these technologies and realize their full potential and benefits. If utilized properly, these technologies can aid engineers in their field by automating monotonous and routine duties, freeing time and space to make more effective and data-driven strategic decisions. This eliminates the monotony of engineers' work and allows them to utilize their skills and competencies to their fullest capacity. The current study identifies the shift of the engineering field towards digitalization and automation, which necessitates a paradigm shift not only in industries but also in educational systems so that future engineers can enter the area with the skills and capabilities to make effective use of digital technologies. In addition to skill development, efforts should be made to ensure digital infostructure availability and the resources required to implement and integrate these technologies effectively. The opportunities associated with these emerging technologies cannot be completely realized until this occurs.

Theoretical Implications

Theoretically, the findings of this study contribute to the engineering corpus of knowledge by providing a comprehensive and current overview of engineering research methods. These findings can assist researchers in gaining a deeper understanding of the engineering landscape and the emerging trends currently shaping the discipline. Very few studies have presented the trend analysis of engineering research as synthesized as in this study; consequently, this study provides information about the most recent advancements and emergent technologies in engineering. The critical analysis and synthesis of the past available literature provide a comprehensive overview that significantly contributes to the body of knowledge. Such a comprehensive overview provides a snapshot of the existing literature in a single source, a valuable resource for researchers in the field. In addition, the researchers can use these findings as a baseline and basis for future research on engineering research methods and their impact on engineering practice. This study can serve as a starting point for planning and executing future research projects involving a literature synthesis.

Practical Implications

The practical implications of this study's findings may interest engineering professionals. Engineers can use these results to inform their practice and make informed judgments about adopting these research methods. Engineers can evaluate their practices in light of current trends. They can utilize current engineering practices and their benefits, as utilized by other engineers in the field. This study provides an overview of the opportunities and challenges associated with the most recent advancements in the engineering field discussed in the current research, which can be useful for engineers in making decisions regarding incorporating these technologies into their systems. Engineering educators can also use these findings to design and revise engineering curricula to reflect current trends in engineering research methods. The recent technological advancement in the field necessitates a revision of the existing curriculum of engineering studies to produce competent and skilled engineers who are prepared to deal with and make optimal use of the most recent technological advancements in the field and overcome the associated challenges.

Limitations and Recommendations

Nevertheless, this research has limitations. Due to its reliance on literature evaluation, the findings are constrained by the quality and quantity of available literature on engineering research methods. This research relies significantly on the quality of the studies cited in the existing literature, which serves as its foundation. In addition, despite endeavors to cover a wide range of research methods and engineering contexts, it is possible that some methods or contexts were not exhaustively covered. This is because some research articles are inaccessible, and others may have been neglected due to human error.

For future research, it is recommended to investigate each of the research methods identified in this study in greater depth. For instance, research could be conducted on how artificial intelligence and machine learning alter engineering practices in various fields. The more targeted approach will permit a detailed analysis and may open the door to adopting a case study approach, which can provide valuable insights by analyzing a real-world scenario. In addition, research could be conducted on how engineers adapt to these most recent trends and the difficulties they face. This may involve analyzing the engineers' behaviors, attitudes, and preferences regarding utilizing the latest technologies in their industry and how comfortable or difficult they find these technologies.

Conclusion

The study's purpose was to critically analyze the current engineering trends arising from the available literature. The recent conceptual investigation confirmed that modeling and simulation, machine learning and artificial intelligence, and complex systems engineering are substantially transforming the engineering field. Multiple engineering fields, ranging from civil engineering to systems engineering, are experiencing increased innovation and productivity due to these techniques. Adoption of these innovative research methodologies presents both significant opportunities and obstacles. The opportunities include efficient and innovative practices that lead to increased automation and digitalization of systems, enabling engineers to make more informed and data-driven decisions. At the same time, routine and monotonous tasks are handled by digital technologies such as AI, machine learning, simulation, modeling, etc.

On the other hand, the obstacles include the need for new competencies and skills, as well as substantial resources, such as cost, time, digital infrastructure, and simple access to large data sets. This study's findings contribute to engineering theory by supplying current information on engineering research methods. In a practical sense, these findings can enlighten engineers about innovative techniques they can implement and aid educators in designing and revising engineering curricula. Researchers can also benefit from this study, as it can serve as a basis for future studies. This study synthesizes the existing literature from a single source, which is useful for researchers. In addition, this study emphasizes the need for further in-depth research on each identified research method individually for a more focused approach to gain a deeper understanding and analysis of each of these methods. Future research could investigate how these techniques alter engineering practice in various disciplines and how engineers adapt to these new developments.

References

Abi Akle, A., Yannou, B., & Minel, S. (2019). Information visualisation for efficient knowledge discovery and informed decision in design by shopping. Journal of Engineering Design, 30(6), 227-253. https://doi.org/10.1080/09544828.2019.1623383

Adams, R., Evangelou, D., English, L., De Figueiredo, A. D., Mousoulides, N., Pawley, A. L., Schiefellite, C., Stevens, R., Svinicki, M., & Trenor, J. M. (2011). Multiple perspectives on engaging future engineers. Journal of Engineering Education, 100(1), 48-88. https://doi.org/10.1002/j.2168-9830.2011.tb00004.x

Alarcón, I. V., & Anwar, S. (2022). Situating multi-modal approaches in engineering education research. Journal of Engineering Education, 111(2), 277-282. https://doi.org/10.1002/jee.20460

Ali, H. B., Langen, T., & Falk, K. (2022). Research methodology for industry-academic collaboration–a case study. INCOSE International Symposium, 32, 187-201. https://doi.org/10.1002/iis2.12908

Beale, D., McKinney, D., Oosthuizen, R., Smith, G., & Watson, M. D. (2022). System Engineering Heuristics for Complex Systems. INCOSE International Symposium, 32(1), 293-312. https://doi.org/10.1002/iis2.12932

Blessing, L. T., & Chakrabarti, A. (2009). DRM: A Design Research Methodology. Springer. https://doi.org/10.1007/978-1-84882-587-1_2

Çetin, M., & Demircan, H. Ö. (2020). Empowering technology and engineering for STEM education through programming robots: A systematic literature review. Early Child Development and Care, 190(9), 1323-1335. https://doi.org/10.1080/03004430.2018.1534844

Chopra, D., & Arora, P. (2022). Swarm Intelligence in Data Science: Challenges, Opportunities and Applications. Procedia Computer Science, 215, 104-111. https://doi.org/10.1016/j.procs.2022.12.012

Chowdhury, S., & Schoen, M. P. (2020). Research paper classification using supervised machine learning techniques. In 2020 Intermountain Engineering, Technology and Computing (IETC) (pp. 1-6). IEEE. https://doi.org/10.1109/IETC47856.2020.9249211

Ciston, S. (2019). Intersectional AI is essential: polyvocal, multimodal, experimental

methods to save artificial intelligence. Journal of Science and Technology of the Arts, 11(2), 3-8. https://doi.org/10.7559/citarj.v11i2.665
Clark, J. S., Porath, S., Thiele, J., & Jobe, M. (2020). Action Research. New Prairie Press. https://newprairiepress.org/ebooks/34
Conde, M. Á., Rodríguez-Sedano, F. J., Fernández-Llamas, C., Gonçalves, J., Lima, J., & García-Peñalvo, F. J. (2021). Fostering STEAM through challenge-based learning, robotics, and physical devices: A systematic mapping literature review. Computer Applications in Engineering Education, 29(1), 46-65. https://doi.org/10.1002/cae.22354
Cooper, R. (2019). Design research–Its 50-year transformation. Design Studies, 65, 6-17. https://doi.org/10.1016/j.destud.2019.10.002
Creswell, J. W. (2003). Research Design: Qualitative, Quantitative and Mixed Methods Approaches. Sage Publications. https://us.sagepub.com/en-us/nam/research-design/book270550
Creswell, J. W. (2021). A Concise Introduction to Mixed Methods Research. Sage Publications. https://us.sagepub.com/en-us/nam/a-concise-introduction-to-mixed-methods-research/book266037
Darmawansah, D., Hwang, G.-J., Chen, M.-R. A., & Liang, J.-C. (2023). Trends and research foci of robotics-based STEM education: a systematic review from diverse angles based on the technology-based learning model. International Journal of STEM Education, 10(1), 1-24. https://doi.org/10.1186/s40594-023-00400-3
Dhar, V. (2013). Data science and prediction. Communications of the ACM, 56(12), 64-73. https://doi.org/10.1145/2500499
Diallo, S., Mittal, S., & Tolk, A. (2018). Research Agenda for Next-Generation Complex Systems Engineering. In Emergent Behavior in Complex Systems Engineering: A Modeling and Simulation Approach (pp. 370-389). John Wiley & Sons. https://doi.org/10.1002/9781119378952.ch16
Dimiduk, D. M., Holm, E. A., & Niezgoda, S. R. (2018). Perspectives on the impact of machine learning, deep learning, and artificial intelligence on materials, processes, and structures engineering. Integrating Materials and Manufacturing Innovation, 7, 157-172. https://doi.org/10.1007/s40192-018-0117-8
Dźwigoł, H. (2019). Research methods and techniques in new management trends: research results. Virtual Economics, 2(1), 31-48. https://doi.org/10.34021/ve.2019.02.01(2)
English, L. D. (2016). STEM education K-12: Perspectives on integration. International Journal of STEM Education, 3(3), 1-8. https://doi.org/10.1186/s40594-016-0036-1
Escudero-Mancebo, D., Fernández-Villalobos, N., Martin-Llorente, O., & Martínez-Monés, A. (2023). Research methods in engineering design: a synthesis of recent studies using a systematic literature review. Research in Engineering Design, 34(2), 221-256. https://doi.org/10.1007/s00163-022-00406-y
Finelli, C. (2018). A Taxonomy for the Field of Engineering Education Research. Taxonomy. https://taxonomy.engin.umich.edu/taxonomy/eer-taxonomy-version-1-1/
Fujimoto, R., Bock, C., Chen, W., Page, E., & Panchal, J. H. (2017). Research Challenges in Modeling and Simulation for Engineering Complex Systems. Springer. https://doi.org/10.1007/978-3-319-58544-4
Glänzel, W., & Schubert, A. (2003). A new classification scheme of science fields and subfields designed for scientometric evaluation purposes. Scientometrics, 56(3), 357-367. https://doi.org/10.1023/A:1022378804087
Goecks, L. S., Souza, M. d., Librelato, T. P., & Trento, L. R. (2021). Design Science Research in practice: review of applications in Industrial Engineering. Gestão & Produção, 28(4). https://doi.org/10.1590/1806-9649-2021v28e5811
Gyory, J. T., Cagan, J., & Kotovsky, K. (2019). Are you better off alone? Mitigating the underperformance of engineering teams during conceptual design through adaptive

process management. Research in Engineering Design, 30, 85-102. https://doi.org/10.1007/s00163-018-00303-3

Han, J., Forbes, H., & Schaefer, D. (2021). An exploration of how creativity, functionality, and aesthetics are related in design. Research in Engineering Design, 32(3), 289-307. https://doi.org/10.1007/s00163-021-00366-9

Herzog, E., Larsson, Å. N., Sundin, O., & Goman, A. F. (2022). A 4-Box Development Model for Complex Systems Engineering. INCOSE International Symposium, 32(1), 233-248. https://doi.org/10.1002/iis2.12928

Ho, L., & Goethals, P. (2022). Machine learning applications in river research: Trends, opportunities and challenges. Methods in Ecology and Evolution, 13(11), 2603-2621. https://doi.org/10.1111/2041-210X.13992

Huutoniemi, K., Klein, J. T., Bruun, H., & Hukkinen, J. (2010). Analyzing interdisciplinarity: Typology and indicators. Research Policy, 39(1), 79-88. https://doi.org/10.1016/j.respol.2009.09.011

Ibrahim, C. K. I. C., Manu, P., Belayutham, S., Mahamadu, A.-M., & Antwi-Afari, M. F. (2022). Design for safety (DfS) practice in construction engineering and management research: A review of current trends and future directions. Journal of Building Engineering, 52, 104352. https://doi.org/10.1016/j.jobe.2022.104352

Johnston, E., Burleigh, C., & Wilson, A. (2020). Interdisciplinary Collaborative Research for Professional Academic Development in Higher Education. Higher Learning Research Communications, 10(1), 62-77. https://doi.org/10.18870/hlrc.v10i1.1175

Kamiri, J., & Mariga, G. (2021). Research methods in machine learning: A content analysis. International Journal of Computer and Information Technology, 10(2), 78-91. https://doi.org/10.24203/ijcit.v10i2.79

Khaleel, M., Ahmed, A. A., & Alsharif, A. (2023). Artificial Intelligence in Engineering. Brilliance: Research of Artificial Intelligence, 3(1), 32-42. https://doi.org/10.47709/brilliance.v3i1.2170

Kitchenham, B., Brereton, O. P., Budgen, D., Turner, M., Bailey, J., & Linkman, S. (2009). Systematic literature reviews in software engineering–a systematic literature review. Information and Software Technology, 51(1), 7-15. https://doi.org/10.1016/j.infsof.2008.09.009

Klavans, R., & Boyack, K. W. (2017). Which type of citation analysis generates the most accurate taxonomy of scientific and technical knowledge? Journal of the Association for Information Science and Technology, 68(4), 984-998. https://doi.org/10.1002/asi.23734

Lattuca, L. R., Knight, D., & Bergom, I. (2013). Developing a measure of interdisciplinary competence. The International Journal of Engineering Education, 29(3), 726-739. https://doi.org/10.18260/1-2--21173

Lê, J. K., & Schmid, T. (2022). The practice of innovating research methods. Organizational Research Methods, 25(2), 308-336. https://doi.org/10.1177/1094428120935498

McNair, L. D., Davitt, M., & Batten, G. P. (2015). Outside the 'comfort zone': impacts of interdisciplinary research collaboration on research, pedagogy, and disciplinary knowledge production. Engineering Studies, 7(1), 47-79. https://doi.org/10.1080/19378629.2015.1014817

McNair, L. D., Newswander, C., Boden, D., & Borrego, M. (2011). Student and faculty interdisciplinary identities in self-managed teams. Journal of Engineering Education, 100(2), 374-396. https://doi.org/10.1002/j.2168-9830.2011.tb00018.x

Mejia, J. A., Revelo, R. A., Villanueva, I., & Mejia, J. (2018). Critical theoretical frameworks in engineering education: An anti-deficit and liberative approach. Education Sciences, 8(4), 1-13. https://doi.org/10.3390/educsci8040158

Meyer, J., Weiss, L., Longmeier, M. M., Gopalakrishnan, S., Hayde, D., & Cai, M. (2022).

How interdisciplinary collaboration helps communicate engineering research to community audiences. In 2022 ASEE Annual Conference & Exposition, Minneapolis, MN. American Society for Engineering Education. http://hdl.handle.net/1811/101836
Muller, G. (2013). Systems engineering research methods. Procedia Computer Science, 16, 1092-1101. https://doi.org/10.1016/j.procs.2013.01.115
Nugroho, P. A., Anna, N. E. V., & Ismail, N. (2023). The shift in research trends related to artificial intelligence in library repositories during the coronavirus pandemic. Library Hi Tech. https://doi.org/10.1108/LHT-07-2022-0326
Okamura, K. (2022). Scientometric engineering: Exploring citation dynamics via arXiv eprints. Quantitative Science Studies, 3(1), 122-146. https://doi.org/10.1162/qss_a_00174
Okunlaya, R. O., Syed Abdullah, N., & Alias, R. A. (2022). Artificial intelligence (AI) library services innovative conceptual framework for the digital transformation of university education. Library Hi Tech, 40(6), 1869-1892. https://doi.org/10.1108/LHT-07-2021-0242
Redstrom, J. (2017). Making design theory. MIT Press. https://mitpress.mit.edu/9780262341851/making-design-theory
Renzi, C., Leali, F., & Di Angelo, L. (2017). A review on decision-making methods in engineering design for the automotive industry. Journal of Engineering Design, 28(2), 118-143. https://doi.org/10.1080/09544828.2016.1274720
Sachini, E., Sioumalas-Christodoulou, K., Christopoulos, S., & Karampekios, N. (2022). AI for AI: Using AI methods for classifying AI science documents. Quantitative Science Studies, 3(4), 1119–1132. https://doi.org/10.1162/qss_a_00223
Saldaña, J. (2021). The Coding Manual for Qualitative Researchers. Sage Publications. https://us.sagepub.com/en-us/nam/the-coding-manual-for-qualitative-researchers/book273583
Sheard, S. (2006). Definition of the sciences of complex systems. Insight, 9(1), 25-26. https://doi.org/10.1002/inst.20069125
Sheard, S. A., & Mostashari, A. (2009). Principles of complex systems for systems engineering. Systems Engineering, 12(4), 295-311. https://doi.org/10.1002/sys.20124
Shin, Y. C., & Xu, C. (2017). Intelligent systems: modeling, optimization, and control. CRC press. https://doi.org/10.1201/9781420051773
Sinha, R., Paredis, C. J., Liang, V.-C., & Khosla, P. K. (2001). Modeling and simulation methods for design of engineering systems. Journal of Computing and Information Science in Engineering, 1(1), 84-91. https://doi.org/10.1115/1.1344877
Sofian, H., Yunus, N. A. M., & Ahmad, R. (2022). Systematic mapping: Artificial intelligence techniques in software engineering. IEEE Access, 10, 51021-51040. https://doi.org/10.1109/ACCESS.2022.3174115
Sokolowski, J. A., & Banks, C. M. (2011). Principles of modeling and simulation: a multidisciplinary approach. John Wiley & Sons. https://doi.org/10.1002/9780470403563
Tempelaar, D., Rienties, B., & Nguyen, Q. (2020). Subjective data, objective data and the role of bias in predictive modelling: Lessons from a dispositional learning analytics application. PLoS One, 15(6), e0233977. https://doi.org/10.1371/journal.pone.0233977
Thai, H.-T. (2022). Machine learning for structural engineering: A state-of-the-art review. Structures, 38, 448-491. https://doi.org/10.1016/j.istruc.2022.02.003
Thiel, D. V. (2014). Research methods for engineers. Cambridge University Press. http://www.cambridge.org/9781107034884
Tolk, A., Diallo, S., & Mittal, S. (2018). Complex systems engineering and the challenge

of emergence. In Emergent Behavior in Complex Systems Engineering: A Modeling and Simulation Approach (pp. 78-97). John Wiley & Sons. https://doi.org/10.1002/9781119378952.ch5

Ursić, L., Baldacchino, G., Bašić, Ž., Sainz, A. B., Buljan, I., Hampel, M., Kružić, I., Majić, M., Marušić, A., & Thetiot, F. (2022). Factors Influencing Interdisciplinary Research and Industry-Academia Collaborations at Six European Universities: A Qualitative Study. Sustainability, 14(15), 9306. https://doi.org/10.3390/su14159306

Van den Beemt, A., MacLeod, M., Van der Veen, J., Van de Ven, A., Van Baalen, S., Klaassen, R., & Boon, M. (2020). Interdisciplinary engineering education: A review of vision, teaching, and support. Journal of Engineering Education, 109(3), 508-555. https://doi.org/10.1002/jee.20347

Van den Berghe, R., Verhagen, J., Oudgenoeg-Paz, O., Van der Ven, S., & Leseman, P. (2019). Social robots for language learning: A review. Review of Educational Research, 89(2), 259-295. https://doi.org/10.3102/0034654318821286

Van der Aalst, W. M. (2014). Data scientist: The engineer of the future. In Enterprise Interoperability VI: Interoperability for Agility, Resilience and Plasticity of Collaborations (pp. 13-26). Springer. https://doi.org/10.1007/978-3-319-04948-9_2

Wohlin, C., & Runeson, P. (2021). Guiding the selection of research methodology in industry–academia collaboration in software engineering. Information and Software Technology, 140, 106678. https://doi.org/10.1016/j.infsof.2021.106678

Yig, K. G. (2022). Research Trends in Mathematics Education: A Quantitative Content Analysis of Major Journals 2017-2021. Journal of Pedagogical Research, 6(3), 137-153. https://doi.org/10.33902/JPR.202215529