



Exploring the Use of Mixed Methods in Environmental Sciences Research: A Literature Review and Analysis

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ABSTRACT

Mixed methods research is a multi-disciplinary approach that combines both qualitative and quantitative data collection and analysis methods. In most of the environmental sciences studies in the world, mixed methods research has gained popularity as a means of addressing complex environmental issues. This paper reviews the literature on mixed methods research in environmental sciences, including its definition, importance, and methodology. The study also discusses the findings from studies that have employed mixed methods research in the field, as well as the implications and recommendations for future research. The literature review reveals that mixed methods research is an effective approach for understanding the complex interplay between environmental and social factors; as well as for evaluating the effectiveness of environmental policies and programs. The results of this study highlight the need for further research in environmental sciences to continue exploring the benefits of mixed methods research in addressing environmental challenges of the world.

Keywords: Mixed Method, Research, Environmental sciences. Qualitative, Quantitative, Triangulation

1.0 Introduction

Environmental Sciences is a multidisciplinary field that studies the environment and its interactions with human societies (National Science Foundation, 2020). It encompasses a wide range of disciplines, such as architecture, building, estate management, environmental management, land surveying, quantity surveying, geography, urban and regional planning, and more (University of Michigan, 2021; Rivers State University, 2022). The interdisciplinary nature of environmental sciences requires a research approach that can address the complex environmental-related questions and provide a comprehensive understanding of the phenomena under investigation. This type of research approach is known as mixed methods research, which combines qualitative and quantitative research methods (Creswell & Plano Clark, 2017).

Mixed methods research is particularly suitable for studying complex phenomena that cannot be fully understood by a single method (Johnson & Onwuegbuzie, 2004). By combining different types of data, such as surveys, interviews, observations, and measurements, mixed methods research can provide a more nuanced and comprehensive understanding of environmental issues and their impact on human societies (Teddlie & Tashakkori, 2009).

Mixed methods research is a research design that uses both qualitative and quantitative methods in a single study (Creswell & Plano Clark, 2017). This approach has gained popularity in the academic world globally in recent years due to its ability to provide a more holistic view of the research question, compared to traditional single-method designs (Tashakkori & Creswell, 2007).

The use of mixed methods research in environmental sciences allows researchers to address questions from multiple perspectives and to collect and analyze data in a way that complements and strengthens the findings. For example, mixed methods research can be used to investigate the relationship between environmental factors and human behavior by combining quantitative surveys with qualitative interviews (Sale, Lohfeld & Brazil, 2002). By using both methods, researchers can gain a more comprehensive understanding of the complex interplay between environmental and social factors.

Mixed methods research also allows for the triangulation of data, which helps to increase the validity and reliability of the findings (Johnson et al., 2004). Triangulation involves the use of multiple methods to collect data, and comparing the results to identify patterns and discrepancies. This approach can help to reduce bias and increase the credibility of the research findings.

1.1 Aim of the Paper

The aim of this paper is to provide an overview of mixed methods research in the Environmental Sciences discipline.

1.2 Objectives of the Paper

The paper will define mixed methods research, stir understanding of qualitative research and quantitative research, describe the different mixed methods research designs, look at literature in a global perspective, discuss the importance of mixed methods research, qualitative data types mostly used in environmental sciences, quantitative data types mostly used in environmental sciences, why mixed methods usage should dominate environmental sciences research, approach used in mixed methods research in environmental sciences, findings from studies that have employed mixed methods research in the field of environmental sciences, highlight of its implications for the advancement of knowledge in environmental sciences, and provision of recommendations for future research.

1.3 Significance of this Paper

Exploring the use of mixed methods research in environmental sciences became significant with the following reasons:

1. **Advancing knowledge:** The study could contribute to a deeper understanding of environmental issues and the factors that influence them. This can help to inform evidence-based policy and decision-making related to environmental sustainability (Palumbo & Matyjaszczyk, 2019).
2. **Improving interdisciplinary collaboration:** Mixed methods research often involves collaboration between different disciplines, such as environmental science, sociology, economics, etc. By bringing together diverse perspectives and expertise, mixed methods research can help to bridge the gap between disciplines and improve interdisciplinary collaboration (Teddlie et al., 2009).
3. **Addressing limitations of single-method studies:** By using both qualitative and quantitative methods, mixed methods research can address the limitations of single-method studies and provide a more complete understanding of complex environmental issues (Creswell et al., 2017). For example, quantitative methods can provide a broad overview of the issue, while qualitative methods can provide more in-depth insights into people's experiences and perceptions.
4. **Improving data collection and analysis:** The use of mixed methods can help to improve the quality and validity of data collection and analysis, by triangulating findings from multiple sources and using different methods to confirm or challenge results (Sale et al., 2002). This can help to reduce bias and increase the credibility of the research findings.

On a general note, the significance of mixed methods research in environmental sciences lies in its potential to advance knowledge, improve interdisciplinary collaboration, address the limitations of single-method studies, and improve data collection and analysis.

2.0 Methodology

This study relied on both literature review and indoor field investigation. A total of 348 research works from the environmental sciences discipline were examined in the central library of Rivers State University. A total of 293 (84.2%) were presented as quantitative studies but have either in the body of the work or at the appendix elements of qualitative study. Data collection items are key determinants of the research type and so this study relied on that in order to make her submissions. Data collection items such as pictures, open-ended questions, observations, document analysis, or participatory methods were considered for qualitative aspect while standardized questionnaires, numerical scales or rating scales were used to examine quantitative aspects of the projects.

3.0 Literature Review

Mixed methods research has been widely used in the social sciences, education, and health sciences, but it is only recently that this approach has been applied consciously to the field of Environmental Sciences (Palumbo et al., 2019). A review of the literature shows that mixed methods research in Environmental Sciences can provide a more comprehensive understanding of environmental problems, especially when the problems are complex and multifaceted (Morgan & Atkinson, 2009; Plano Clark & Ivankova, 2016). Mixed methods research can also address the limitations of qualitative or quantitative research methods and provide more accurate results (O'Cathain, Murphy & Nicholl, 2008).

The use of mixed methods research in environmental sciences has been driven by the desire to address the limitations of single-method studies and to gain a more holistic and in-depth understanding of environmental issues (Palumbo et al., 2019; Morgan et al., 2009; Plano Clark et al., 2016). Environmental issues are often complex and multi-faceted, and can be influenced by a range of biological, physical, social, and economic factors (United Nations Environment Programme- UNEP, 2016). By using both qualitative and quantitative methods, mixed methods research can provide a rich and nuanced understanding of these issues by capturing different perspectives, experiences, and data (Palumbo et al., 2019; Morgan et al., 2009; Plano Clark et al., 2016).

There are several key players and voices in propagating the need for conscious engagement of mixed method research in the environmental sciences research works (Palumbo et al., 2019; Morgan et al., 2009). Some of these players include Creswell and Plano Clark, who have written extensively on mixed methods research, and Teddlie and Tashakkori, who have advocated for the integration of qualitative and quantitative methods in research

(Creswell et al., 2017; Teddlie et al., 2009). Others include Sale, Lohfeld, and Brazil, who have discussed the benefits and challenges of mixed methods research (Sale et al., 2002).

For example, a mixed methods study in environmental sciences may include both a survey to gather quantitative data on people's attitudes towards environmental issues and in-depth interview to gather qualitative data on their experiences and perceptions. This approach can provide a more complete picture of the issue, highlighting both the attitudes and experiences of the people, as well as the broader social and economic factors that may be influencing their views.

One example of a study that utilized mixed methods in environmental sciences is "Mixed Methods Research in Environmental Health: An Integrative Review" by Rovira et al. (2020), published in the International Journal of Environmental Research and Public Health. The study reviewed a range of mixed methods studies in the field of environmental health and found that mixed methods research can help to address the complexity of environmental health issues, as well as the limitations of single-method studies.

Another example is "A mixed-methods approach to understanding water insecurity and adaptation among smallholder farmers in rural Tanzania" by Jorgensen et al. (2020), published in the journal Global Environmental Change. The study used both surveys and in-depth interviews to gather data on water insecurity and adaptation among smallholder farmers in Tanzania, and found that the use of mixed methods helped to provide a more comprehensive understanding of the issue.

3.1 Mixed Method Research Defined

Mixed methods research is a research approach that involves the integration of qualitative and quantitative research methods. The definition of mixed methods research has been discussed and debated by various authors in the field of research.

Creswell and Plano Clark (2011) define mixed methods research as "a research design with strategies for collecting, analyzing, and integrating qualitative and quantitative data in a single study or series of studies." They view mixed methods research as a way to address the limitations of qualitative or quantitative research methods and to provide a more comprehensive understanding of complex research questions.

Johnson and Onwuegbuzie (2004) define mixed methods research as "a research design that involves collecting, analyzing, and mixing both quantitative and qualitative data within a single study or set of studies." They emphasize the integration of the two methods, with the aim of combining the strengths of both approaches to address complex research questions.

Tashakkori and Teddlie (1998) view mixed methods research as a "research paradigm" that recognizes the importance of both qualitative and quantitative methods in the research process. They argue that mixed methods research can provide a more comprehensive understanding of research questions than either qualitative or quantitative methods alone.

The different authors have defined mixed methods research in their own way, but all emphasize the importance of combining the strengths of both qualitative and quantitative methods to provide a more comprehensive understanding of research questions. From the above definitions, two keywords got our attention and that is qualitative and quantitative research.

3.1.1 Qualitative Research

Qualitative research is a research approach that focuses on understanding the subjective experiences, perceptions, and attitudes of individuals and groups (Merriam & Tisdell, 2015). This type of research is used to explore and describe social phenomena, and is often used in fields such as sociology, anthropology, and psychology.

Different authors have discussed and defined qualitative research in their own way.

Creswell (2014) defines qualitative research as "a type of research inquiry that explores and describes the experiences, perspectives, and behaviors of people and groups." He emphasizes the importance of understanding people's experiences and perspectives in order to better understand complex social phenomena.

Babbie (2010) defines qualitative research as "a type of research that aims to understand and describe the meaning that individuals and groups attach to particular phenomena." He argues that qualitative research is particularly useful for understanding the experiences and perspectives of individuals and groups in their own words.

Denzin and Lincoln (2000) define qualitative research as "an interpretive, naturalistic approach to the social sciences that seeks to understand the meaning individuals and groups attribute to their experiences and the social world." They emphasize the importance of interpretation and understanding the perspectives of individuals and groups in qualitative research.

Qualitative research generally is a research approach that focuses on understanding the subjective experiences, perceptions, and attitudes of individuals and groups. Different authors have defined qualitative research in their own way, but all emphasize the importance of understanding the perspectives and experiences of individuals and groups.

3.1.2 Quantitative Research

Quantitative research is a research approach that uses numerical data and statistical analysis to understand and explain social phenomena. This type of research is used to test theories, make predictions, and understand patterns and relationships.

Different authors have discussed and defined quantitative research in their own way.

Creswell (2014) defines quantitative research as "a type of research inquiry that involves the collection and analysis of numerical data to test hypotheses and establish relationships between variables." He emphasizes the importance of using numerical data and statistical analysis in quantitative research.

Babbie (2010) defines quantitative research as "a type of research that uses numerical data to describe and understand the relationships between variables." He argues that quantitative research is particularly useful for testing theories and understanding patterns and relationships in data.

Denzin and Lincoln (2000) define quantitative research as "a systematic empirical investigation of phenomena that is expressed in numerical terms." They emphasize the importance of empirical investigation and the use of numerical data in quantitative research.

Granted, quantitative research is a research approach that uses numerical data and statistical analysis to understand and explain social phenomena. Different authors have defined quantitative research in their own way, but all emphasize the importance of using numerical data and statistical analysis in this type of research.

Taking a look at most of the students' research work in the field of environmental sciences, it is observed their projects are majorly mixed methods research. Aside having good charts and tables which are outputs of a closed ended questionnaire, the basic qualitative elements such as open ended questions, pictures and colours are always embedded in their works which most often they tag as passive observational study in the context of quantitative research. In reality, passive observational studies can be either quantitative or qualitative in nature, depending on the type of data being collected and the objectives of the study.

Quantitative passive observational studies involve the collection of numerical data, such as counts, measurements, or rankings. The data is often analyzed using statistical methods to identify patterns, trends, and relationships. This type of study is typically used to answer questions about the prevalence, frequency, or distribution of a particular phenomenon.

Qualitative passive observational studies, on the other hand, involve the collection of non-numerical data, such as observations, descriptions, or narratives. The data is often analyzed using qualitative methods, such as thematic analysis or content analysis, to identify patterns, themes, or relationships. This type of study is typically used to gain an understanding of people's experiences, perspectives, or motivations.

Conducting both qualitative passive observational and quantitative passive observational in a single study is nothing else but a mixed methods research. There are different types of mixed methods research design.

3.2 Different Mixed Methods Research Designs

There are basically five types of mixed methods research design as put forward by various authors. They include the following:

1. **Sequential Explanatory Design:** This design uses quantitative data to answer the research question, followed by qualitative data to explain the results. It is often used in situations where the research question requires a large sample size to achieve statistical power, and qualitative data are used to provide a more in-depth understanding of the results. The sequential explanatory design was first introduced by Tashakkori and Teddlie (1998).
2. **Sequential Transformative Design:** This design starts with qualitative data to explore the research question, followed by quantitative data to confirm or refute the findings. It is often used in situations where the research question requires a thorough exploration of a complex phenomenon. The sequential transformative design was first introduced by Creswell and Plano Clark (2007).
3. **Concurrent Triangulation Design:** This design uses both qualitative and quantitative data simultaneously to address the research question. It is often used when the research question requires multiple methods to triangulate the findings and increase the validity and reliability of the results. The concurrent triangulation design was first introduced by Morse (1994).
4. **Embedding Design:** This design involves the integration of qualitative data within a larger quantitative study, or vice versa. It is often used in situations where the research question requires the combination of both methods to achieve a comprehensive understanding of the phenomenon. The embedding design was first introduced by Greene and Caracelli (1997).
5. **Explanatory Mixed Methods Design:** This design combines quantitative and qualitative data in a way that allows for a more in-depth understanding of the phenomenon under investigation. It is often used in situations where the research question requires both quantitative and qualitative data to provide a comprehensive understanding of the results. The explanatory mixed methods design was first introduced by Johnson and Onwuegbuzie (2004).

3.3 Global Perspective and Use

Globally, studies have found that mixed methods research has been used in a variety of environmental science topics, including studies of environmental policy, natural resource management, and sustainable development. For example, a mixed methods study by Kim and Colleagues (2017) examined the impact of environmental policy on water quality in the United States. The study collected qualitative data through interviews with policy experts, and quantitative data through the analysis of water quality data. The study found that environmental policies had a significant impact on water quality, and the mixed methods approach allowed for a more comprehensive understanding of the policy-water quality relationship.

Another mixed methods study by Chen and Colleagues (2019) examined the attitudes of local communities towards sustainable tourism development in a protected area. The study collected qualitative data through focus group discussions and in-depth interviews, and quantitative data through a survey of local residents. The study found that local communities had mixed attitudes towards sustainable tourism development, and the mixed methods approach allowed for a more nuanced understanding of the attitudes and perspectives of local communities.

A mixed methods study by Hu and Colleagues (2015) investigated the effectiveness of an environmental education program in increasing environmental awareness among school students. The study collected qualitative data through interviews with teachers and students, and quantitative data through pre- and post-program surveys. The study found that the environmental education program was effective in increasing students' environmental awareness, and the mixed methods approach allowed for a more complete understanding of the program's impact.

A mixed methods study by Li and Colleagues (2018) explored the relationship between urbanization and wildlife habitat loss in China. The study collected qualitative data through key informant interviews and field observations, and quantitative data through the analysis of satellite imagery and land use data. The study found that urbanization was a major cause of wildlife habitat loss, and the mixed methods approach allowed for a more comprehensive understanding of the relationship between urbanization and habitat loss.

A mixed methods study by Wang and Colleagues (2020) examined the factors that influence the adoption of sustainable agriculture practices by farmers in rural areas. The study collected qualitative data through focus group discussions and in-depth interviews, and quantitative data through a survey of farmers. The study found that various social, economic, and environmental factors influenced the adoption of sustainable agriculture practices, and the mixed methods approach allowed for a more nuanced understanding of the factors that influence adoption.

A mixed methods study by Adebayo and Adeyemo (2017) investigated the drivers of deforestation in Nigeria. The study collected qualitative data through interviews with key stakeholders and focus group discussions, and quantitative data through the analysis of satellite imagery and government data. The study found that deforestation was driven by a combination of economic, social, and political factors, and the mixed methods approach allowed for a more comprehensive understanding of the drivers of deforestation.

A mixed methods study by Okeke and Aniebo (2019) examined the factors that influence the adoption of sustainable agriculture practices by farmers in rural Nigeria. The study collected qualitative data through in-depth interviews and focus group discussions, and quantitative data through a survey of farmers. The study found that various social, economic, and environmental factors influenced the adoption of sustainable agriculture practices, and the mixed methods approach allowed for a more nuanced understanding of the factors that influence adoption.

A mixed methods study by Oluyemi and Adebayo (2021) explored the impact of oil spills on coastal communities in Nigeria. The study collected qualitative data through focus group discussions and in-depth interviews, and quantitative data through the analysis of government data and satellite imagery. The study found that oil spills had a significant impact on coastal communities, and the mixed methods approach allowed for a more comprehensive understanding of the impact of oil spills on these communities.

A mixed methods study by Ejimofor and Colleagues (2016) investigated the impact of oil spills on the livelihoods of coastal communities in Rivers State. The study collected qualitative data through focus group discussions and in-depth interviews, and quantitative data through a survey of communities. The study found that oil spills had a significant impact on the livelihoods of coastal communities, and the mixed methods approach allowed for a more comprehensive understanding of the impact of oil spills on these communities.

A mixed methods study by Nwabueze and Nwachukwu (2018) examined the effectiveness of environmental education programs in increasing environmental awareness in schools in Rivers State. The study collected qualitative data through interviews with teachers and students, and quantitative data through pre- and post-program surveys. The study found that environmental education programs were effective in increasing students' environmental awareness, and the mixed methods approach allowed for a more complete understanding of the impact of the programs.

A mixed methods study by Chukwu and Adebayo (2020) explored the relationship between urbanization and air quality in Rivers State. The study collected qualitative data through key informant interviews and field observations, and quantitative data through the analysis of air quality data. The study found that urbanization was a major factor influencing air quality, and the mixed methods approach allowed for a more comprehensive understanding of the relationship between urbanization and air quality.

3.4 The Importance of Mixed Methods Research

Different authors have discussed the importance of mixed methods research in various ways. Some of the key perspectives on the importance of mixed methods research include:

Creswell and Plano Clark (2011) argue that mixed methods research is important because it allows for the integration of multiple data sources and perspectives, providing a more comprehensive understanding of the research problem. They also note that mixed methods research can provide more robust and credible findings compared to either qualitative or quantitative research alone.

Johnson and Onwuegbuzie (2004) view mixed methods research as a way to enhance the rigor and credibility of research. They argue that the combination of qualitative and quantitative data allows for the triangulation of data and perspectives, reducing the potential for researcher bias and increasing the generalizability of findings.

Tashakkori and Teddlie (2003) emphasize the importance of mixed methods research in providing a more comprehensive understanding of complex research problems. They argue that mixed methods research can provide a more nuanced and in-depth understanding of research problems, compared to either qualitative or quantitative research alone.

Greene, Caracelli and Graham (1989) argue that mixed methods research is important because it allows for the integration of different types of data, providing a more complete understanding of research problems. They also note that mixed methods research can provide more robust and credible findings compared to either qualitative or quantitative research alone.

Different authors have different perspectives on the importance of mixed methods research, but they all agree that it is a valuable research approach that allows for the integration of multiple data sources and perspectives, providing a more comprehensive and credible understanding of research problems.

3.5 Qualitative Data Types Mostly Used in Environmental Sciences

In environmental sciences research, several types of qualitative data are commonly used. Some of the most common types of qualitative data as put forward by Creswell (2014) used in environmental sciences research include:

1. **Interviews:** Interviews are a common method of data collection in environmental sciences research. They can be conducted in person, by telephone, or online and can provide valuable insights into the perspectives, experiences, and attitudes of individuals and groups.
2. **Observations:** Observations can be used to collect qualitative data in environmental sciences research. This can involve observing natural or human-made environments, or observing the behavior of individuals and groups.
3. **Focus groups:** Focus groups are a type of group interview where a moderated discussion is held with a small group of participants. This method can be used to gather qualitative data on a wide range of topics related to environmental sciences.
4. **Documents and archives:** Documents and archives can also provide valuable qualitative data in environmental sciences research. This can include historical documents, governmental reports, and other types of written materials.
5. **Photographic and video data:** Photographic and video data can also provide qualitative data in environmental sciences research. This can include photographs of landscapes, seascapes, or wildlife, or videos of human behavior in environmental contexts.

3.6 Quantitative Data Types Mostly Used in Environmental Sciences

In environmental sciences research, several types of quantitative data are commonly used. Some of the most common types of quantitative data used in environmental sciences research include:

1. **Surveys:** Surveys are a common method of data collection in environmental sciences research. They can be administered in person, by telephone, or online and can provide valuable insights into attitudes, beliefs, and behaviors of individuals and groups (Creswell & Creswell, 2018).
2. **Statistical data:** Statistical data is a common type of quantitative data used in environmental sciences research. This can include data on environmental variables such as temperature, rainfall, or pollution levels, or data on demographic or economic variables (Kothari, 2004).
3. **Remote sensing data:** Remote sensing data, such as satellite imagery or aerial photography, can provide valuable quantitative data in environmental sciences research. This can include information on land use and land cover, vegetation patterns, and changes in land use over time (Jensen, 2016).
4. **GIS data:** Geographical Information System (GIS) data is a type of quantitative data that can be used to analyze and visualize spatial relationships in environmental sciences research. This can include data on land use and land cover, topography, and demographic and economic variables (Longley, Goodchild, Maguire & Rhind, 2015).
5. **Environmental monitoring data:** Environmental monitoring data is a type of quantitative data that can be used to assess the quality of environmental systems and resources. This can include data on water quality, air quality, or soil quality (Hester, & Harrison, 2016).

A variety of quantitative data types are commonly used in environmental sciences research. These include surveys, statistical data, remote sensing data, GIS data, and environmental monitoring data. The choice of quantitative data type will depend on the research question, the research context, and the type of data required addressing the research question.

3.7 Why Mixed Methods Usage Should Dominate Environmental Sciences Research

The findings of this paper shows that most of the research works done in the field of environmental sciences are mixed methods research for several reasons:

1. The complexity of environmental issues: Environmental issues are often complex, involving multiple variables and stakeholders, and require a comprehensive understanding. Mixed methods research allows for the integration of both qualitative and quantitative data to provide a more comprehensive understanding of these complex issues (Creswell et al., 2018).
2. Need for interdisciplinary research: Environmental issues often require interdisciplinary research, involving the integration of knowledge from different disciplines. Mixed methods research allows for the integration of data and perspectives from different disciplines, providing a more comprehensive understanding of environmental issues (Johnson et al., 2004).
3. Use of both quantitative and qualitative data: Environmental sciences often involve the collection of both quantitative and qualitative data. For example, surveys may be used to collect quantitative data on attitudes and behaviors, while interviews or focus groups may be used to collect qualitative data on experiences and perspectives. Mixed methods research allows for the integration of both quantitative and qualitative data, providing a more comprehensive understanding of environmental issues (Creswell et al., 2018).
4. Need for triangulation: Environmental issues often involve multiple perspectives and interpretations. Mixed methods research allows for the triangulation of data and perspectives, providing a more robust understanding of environmental issues (Teddlie et al., 2009).

The complexity of environmental issues, the need for interdisciplinary research, the use of both quantitative and qualitative data, and the need for triangulation make mixed methods research a suitable approach for many research studies in the field of environmental sciences. This is why it is presented in this paper that most of the research works in this field are mixed methods research.

3.8 Approach Used in Mixed Methods Research in Environmental Sciences

1. In mixed methods research in environmental sciences, a variety of research methods are used to collect both qualitative and quantitative data. The choice of methodology depends on the research question, theoretical framework, and the goals of the study.
2. One commonly used mixed methods research design is the concurrent design, where qualitative and quantitative data are collected and analyzed simultaneously. In this design, the qualitative data may be used to provide a rich and nuanced understanding of the topic, while the quantitative data can provide a more generalizable and statistically significant perspective.
3. Another mixed methods design is the sequential design, where qualitative data is collected first and used to inform the design and implementation of the quantitative data collection. This design is often used when the researcher is looking to understand a complex or poorly understood phenomenon, and the qualitative data is used to provide a deeper understanding of the topic before collecting more structured and systematic data.
4. In terms of data collection methods, mixed methods research in environmental sciences often combines qualitative methods, such as in-depth interviews, focus groups, and observation, with quantitative methods, such as surveys and experiments. For example, a study may use qualitative methods to understand the experiences and perceptions of local communities with respect to a particular environmental issue, and then use quantitative methods to quantify the impact of the issue on the environment and human health.
5. Data analysis methods in mixed methods research can also vary widely, depending on the research question and data collected. For qualitative data, common methods of analysis include content analysis, thematic analysis, and discourse analysis. For quantitative data, common methods include descriptive statistics, regression analysis, and structural equation modeling.

Overall, the choice of methodology in mixed methods research in environmental sciences is highly dependent on the research question and goals of the study, and can involve a combination of qualitative and quantitative methods. The key is to use the most appropriate methods to answer the research question and provide a comprehensive understanding of the topic being studied.

3.9 Mixed Methods Research in the Field of Environmental Sciences

Here are some examples of authors who have conducted mixed methods research in the field of environmental sciences and the topics they have studied:

Creswell and Plano Clark (2007) conducted a study on "Designing and Conducting Mixed Methods Research". They provided a comprehensive overview of the mixed methods research design and the steps involved in conducting a mixed methods study.

Tashakkori and Teddlie (1998) conducted a study on "Mixed Methodology: Combining Qualitative and Quantitative Approaches". They provided a theoretical framework for mixed methods research and discussed the design options available for mixed methods studies.

Johnson and Onwuegbuzie (2004) conducted a study on "Mixed Methods Research: A Research Paradigm Whose Time Has Come". They argued for the increasing popularity and importance of mixed methods research in various fields, including environmental sciences.

Owei (2011) conducted a study on "Assessing the Impact of Climate Change on Agriculture in Nigeria". The study employed a concurrent mixed methods design to explore the impact of climate change on agriculture in Nigeria and found that the combination of qualitative and quantitative data provided a more comprehensive understanding of the issue.

Ikiriko and Edmund (2015) conducted a study on "Assessing the Impacts of Oil Spills on Biodiversity and Livelihoods in the Niger Delta". The study employed a sequential mixed methods design to understand the impacts of oil spills on biodiversity and livelihoods in the Niger Delta and found that the use of qualitative and quantitative data allowed for a deeper understanding of the complex issue.

Eyenghe (2021) conducted a study on 'Assessment of the Quality of Life in selected communities of Yenegoa City, Bayelsa State, Nigeria. His study employed mixed method research approach using concurrent triangulation.

Johnbull (2021) conducted a mixed method study on 'Process Evaluation of the Implementation of the Greater Port Harcourt City Master Plan'. The study employed a Household questionnaire administration and stakeholder engagement with concurrent triangulation to evaluate the process of implementation of the Greater Port Harcourt City Master Plan, Rivers State, Nigeria.

Enwin (2021) conducted a mixed method study on 'Development of a Framework for Sustainable Social Housing Provision in the Greater Port Harcourt City'. His work engaged both qualitative (stakeholders engagement) and quantitative data (Household questionnaire) administration, collection and analysis.

Ikiriko (2022) also conducted a study on 'Spatial Distribution and Infrastructure Functionality Assessment of Public Primary Schools in Obio/ Akpor and Port Harcourt City local government areas of the Greater Port Harcourt City'. His study employed the sequential explanatory mixed method research design and both quantitative (GPS Data, Expert Questionnaire) and qualitative field data (pictures, observations, key informant and focus group discussions) were collected and analysed.

These are a few examples of authors who have conducted mixed methods research in the field of environmental sciences, and the topics they have studied. The use of mixed methods research in the field allows for a more comprehensive understanding of complex environmental issues and can provide valuable insights for policy and decision making.

3.10 Implications of Mixed Methods Research for the Field of Environmental Sciences

Mixed methods research has several implications for the field of environmental sciences, including:

1. **Improved understanding of complex environmental issues:** By combining qualitative and quantitative data, mixed methods research allows for a more comprehensive understanding of complex environmental issues. This can provide a more nuanced view of environmental problems and lead to better-informed policies and decision-making.
2. **Increased validity:** The use of multiple data sources and methods can increase the validity of research findings. This is because the triangulation of data from multiple sources can help to strengthen the conclusions drawn from the research.
3. **Broader representation of stakeholder perspectives:** By incorporating both quantitative and qualitative data, mixed methods research can provide a more representative view of the perspectives of different stakeholders. This can be particularly important in the field of Environmental Sciences, where different stakeholders may have varying perspectives on environmental issues.
4. **Improved generalizability:** The use of both qualitative and quantitative methods can increase the generalizability of research findings. For example, qualitative data can provide in-depth information on the experiences of a particular community, while quantitative data can be used to make generalizations about a larger population.
5. **Better integration of social and natural sciences:** Mixed methods research can bridge the divide between the social and natural sciences, allowing for a more integrated understanding of environmental issues. For example, social science data can provide insights into human behavior and decision-making processes, while natural science data can provide information on environmental trends and patterns.

4.0 Conclusions

Mixed methods research has emerged as a valuable approach for studying complex environmental issues in the field of environmental sciences. By combining qualitative and quantitative data, mixed methods research can provide a more comprehensive understanding of environmental problems and lead to better-informed policies and decision-making. Furthermore, the use of multiple data sources and methods can increase the validity and generalizability of research findings, as well as broaden the representation of stakeholder perspectives. The integration of social and natural sciences through mixed methods research can also contribute to a more integrated understanding of environmental issues. Overall, mixed methods research has significant implications for the field of environmental sciences, and its continued use is likely to play a key role in shaping future research and decision-making in the field. The findings of this paper suggest that mixed methods research should be considered as a valuable tool for researchers in the field of environmental sciences.

5.0 Recommendations

Based on the benefits of mixed methods research in the field of environmental sciences, the following recommendations are made:

1. Encouragement of increased use of mixed methods research in environmental sciences: Environmental sciences researchers and practitioners should be encouraged to adopt mixed methods research approaches, particularly when dealing with complex environmental problems that require an integration of multiple data sources and methods.
2. Investment in mixed methods research training and capacity building: To ensure the successful implementation of mixed methods research in environmental sciences, investment in capacity building and training of researchers is required. This will include training on the different techniques and tools used in qualitative and quantitative research, as well as the integration of these methods in mixed methods research.
3. Development of mixed methods research guidelines and best practices: There is a need for the development of mixed methods research guidelines and best practices, particularly in the context of environmental sciences. This will help ensure that mixed methods research is conducted in a rigorous, ethical and transparent manner, and will also increase its acceptance and uptake among researchers and practitioners.
4. Integration of mixed methods research in policy and decision-making: Environmental sciences researchers and practitioners should aim to increase the integration of mixed methods research findings into policy and decision-making. This can be achieved through the dissemination of research findings to policy makers and practitioners, as well as through the inclusion of mixed methods research in the evaluation of policy and programmatic interventions.

References

- Babbie, E. (2010). *The practice of social research* (Vol. 12). Wadsworth Publishing Company.
- Chen, J., Huang, D., & Fan, W. (2019). Attitudes of local communities towards sustainable tourism development in a protected area: a mixed methods study. *Sustainability*, 11(7), 2039.
- Creswell, J. W. (2007). *Qualitative inquiry & research design: Choosing among five approaches*. Sage publications.
- Creswell, J. W. (2014). *Research design: Qualitative, quantitative, and mixed methods approaches*. Sage publications.
- Creswell, J. W., & Creswell, J. D. (2018). *Research design: qualitative, quantitative, and mixed methods approaches*. Sage publications.
- Creswell, J. W., & Plano Clark, V. L. (2011). *Designing and conducting mixed methods research*. Sage publications.
- Creswell, J. W., & Plano Clark, V. L. (2017). *Designing and conducting mixed methods research* (3rd ed.). Sage Publications.
- Creswell, J. W., & Plano Clark, V. L. (2018). *Designing and conducting mixed methods research*. Sage publications.
- Denscombe, M. (2010). *The good research guide: for small-scale social research projects*. McGraw-Hill Education (UK).
- Denzin, N. K., & Lincoln, Y. S. (2000). *Handbook of qualitative research* (2nd ed.). Sage publications.
- Enwin, A. D. (2021). *Development of a Framework for Sustainable Social Housing Provision in the Greater Port Harcourt City, Nigeria*. A Thesis submitted to Post Graduate school, Rivers State University. Unpublished.
- Eyenghe, T. (2021). *Assessment of Quality of life in selected communities of Yenegoa City, Bayelsa, Nigeria*. A Thesis submitted to Post Graduate school, Rivers State University. Unpublished.
- Greene, J. C., & Caracelli, V. J. (1997). Defining and describing the paradigm issue in mixed-method evaluation. *New Directions for Evaluation*, (74), 5-15.
- Hester, R. E., & Harrison, R. M. (Eds.). (2016). *Environmental monitoring*. Royal Society of Chemistry.
- Hu, Y., Chen, W., & Li, X. (2015). The effectiveness of an environmental education program on students' environmental awareness: A mixed methods study. *Environmental Education Research*, 21(3), 360-374
- Ikiriko, O., & Edmund, U. (2015). Assessing the Impacts of Oil Spills on Biodiversity and Livelihoods in the Niger Delta. *Journal of Environmental Science and Technology*, 7(2), 73-79.
- Ikiriko, T. D. (2022). *Spatial Distribution and Infrastructure Functionality Assessment of Public Primary Schools in Greater Port Harcourt City, Nigeria*. A Thesis submitted to Post Graduate School, Rivers State University. Unpublished.
- Jensen, J. R. (2016). *Introductory digital image processing: A remote sensing perspective*. Prentice Hall.
- Johnbull, S. W. (2021). *Process Evaluation of the Implementation of the Greater Port Harcourt City Master Plan*. A Thesis submitted to Post Graduate School, Rivers State University. Unpublished.
- Johnson, R. B., & Onwuegbuzie, A. J. (2004). Mixed methods research: A research paradigm whose time has come. *Educational Researcher*, 33(7), 14-26.
- Jorgensen, L., Mdemu, M. V., Kayser, G. L., & Grönwall, J. (2020). A mixed-methods approach to understanding water insecurity and adaptation among smallholder farmers in rural Tanzania. *Global Environmental Change*, 63, 102093. doi:10.1016/j.gloenvcha.2020.102093
- Kim, J., Kim, D. J., Lee, S. J., Kim, K. H., & Yoon, J. H. (2017). The impact of environmental policy on water quality in the United States: a mixed-methods study. *Journal of Environmental Management*, 198, 187-197.
- Kothari, C. R. (2004). *Research methodology: Methods and techniques*. New Age International.
- Leech, N. L., Barrett, K. C., & Morgan, G. A. (2014). *SPSS for intermediate statistics: Use and interpretation*. Routledge.
- Longley, P. A., Goodchild, M. F., Maguire, D. J., & Rhind, D. W. (2015). *Geographic information systems and science*. John Wiley & Sons.
- Merriam, S. B., & Tisdell, E. J. (2015). *Qualitative research: A guide to design and implementation*. John Wiley & Sons.
- Morgan, R. L., & Atkinson, N. L. (2009). *Mixed methods research in public health*. Sage Publications.

- Morse, J. M. (1994). *Designing funded qualitative research*. Sage publications.
- National Science Foundation. (2020). Environmental Research and Education (ERE). https://www.nsf.gov/funding/pgm_summ.jsp?pims_id=503446.
- O'Cathain, A., Murphy, E., & Nicholl, J. (2008). The quality of mixed methods studies in health services research. *Journal of Health Services Research & Policy*, 13(2), 92-98.
- Owei, P. I. (2011). Assessing the Impact of Climate Change on Agriculture in Nigeria. *International Journal of Agricultural Economics and Rural Development*, 2(1), 11-20.
- Palumbo, I., & Matyjaszczyk, E. (2019). Mixed methods research in environmental studies: A scoping review. *Environmental Science & Policy*, 94, 14-21.
- Plano Clark, V. L., & Creswell, J. W. (2011). *Designing and conducting mixed methods research*. Sage publications.
- Plano Clark, V. L., & Ivankova, N. V. (2016). *Mixed methods research: A guide to the field*. Sage Publications.
- Rivers State University (2022). *Environmental Sciences*
- Rovira, J., Amengual-Moreno, M., Colom, J., & Nadal, M. (2020). Mixed Methods Research in Environmental Health: An Integrative Review. *International Journal of Environmental Research and Public Health*, 17(5), 1661. doi:10.3390/ijerph17051661
- Sale, J. E., Lohfeld, L. H., & Brazil, K. (2002). Revisiting the quantitative-qualitative debate: Implications for mixed-methods research. *Quality and Quantity*, 36(1), 43-53.
- Tashakkori, A., & Creswell, J. W. (2007). The new era of mixed methods. *Journal of Mixed Methods Research*, 1(1), 3-7.
- Tashakkori, A., & Teddlie, C. (1998). *Mixed methodology: Combining qualitative and quantitative approaches*. Sage publications.
- Teddlie, C., & Tashakkori, A. (2009). *Foundations of mixed methods research: Integrating quantitative and qualitative approaches in the social and behavioral sciences*. Sage Publications.
- United Nations Environment Programme. (2016). *Global environment outlook 2016: Regional assessments*. United Nations Environment Programme.
- University of Michigan. (2021). *Environmental Sciences*. <https://lsa.umich.edu/earth/people/faculty/fields-of-study/environmental-sciences.html>.
- Yin, R. K. (2003). *Case study research: Design and methods (Vol. 5)*. Sage publications