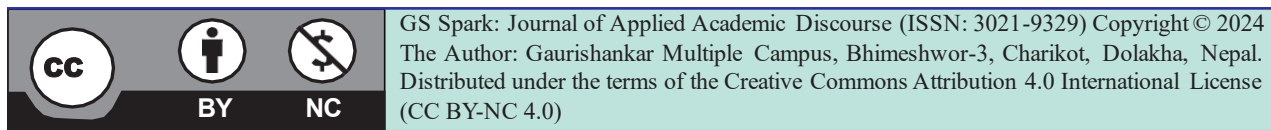




## Critically Analysis of Uses and Limitations of Quantitative Research in Mathematics Education

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### ABSTRACT

Educational research is used to discover new knowledge and theories that involve the combination of reasoning and experience. Education researchers use different education research methods based on their research design and objectives. This paper focused on research design commonly used for quantitative research studies. This paper presents the uses and limitations of quantitative research, highlighting the approach to conducting aims and the advantages and disadvantages of quantitative research in mathematics education. Quantitative research aims to increase students' understanding of the research in mathematics education and improve their comprehension and involvement in the subject. This paper draws on some elementary techniques of quantitative relevant literature and our quantitative research experiences. Quantitative research in mathematics education faces challenges for the effectiveness of student achievement in capturing complexity, requiring significant resources to ensure reliability and addressing oversimplification results. It provides

objectives and measurable data on students' learning and teaching effectiveness, enabling large-scale studies and identifying factors impacting achievement. It is recommended that graduate students and new researchers do quantitative research and help develop evidence-based practices and policies for improved mathematics education.

**Keywords:** education, mathematical knowledge, limitations of mathematics, quantitative, research, uses

## Introduction

Research is a key to investigating new knowledge, facts, and theories. Research is systematic, redefining problems, formulating a hypothesis, or solving the solution by collecting, organizing, and analyzing the data to determine certain conclusions (Kothari, 2010). Research is that knowledge is an orderly search for new practical problems related to various dimensions of daily life in mathematics education. The research method is the search for new facts and is described as a systematic process that consists of representing the extent of the problem, formulating a hypothesis, and collecting the facts or data (Creswell & Creswell, 2017). The classic cyclic research process model consists of a theory generating a hypothesis, testing the hypothesis, and interpreting results (Vanderstoep & Johnston, 2008). This means that research is a systematic procedure of developing and testing new theories, ideas, and practices to enhance the skills and expertise required to sustain a profession. Social research can generate knowledge that supports social standards and helps us improve the problems (Hasan, 2024). Quantitative research is a tool of empirical research that uses numbers for data analysis. It involves gathering absolute data and generating information to understand society's context. Quantitative researchers use an objectivist approach to study society and personal choices about their instruments, such

as surveys and experiments (Cohen, Manion, & Morrison (2007). The purpose of quantitative research is to learn a certain subject or activity by quantifying variables in numerical terms.

Mathematics education is a powerful tool for social justice, enabling marginalized groups to challenge systemic inequalities and address real-world problems. Providing students with the necessary skills to critically engage with societal issues plays an essential role in closing achievement gaps tied to race, ethnicity, or socioeconomic status. In particular, mathematics education can offer equitable opportunities for students who traditionally face educational disadvantages, ensuring that all learners have access to quality instruction and resources (Gutstein, 2006; Boaler, 2016). Through the development of problem-solving abilities and analytical thinking, mathematics education empowers students, enabling them to contribute meaningfully to their communities. The discipline equips learners with skills necessary for social mobility, career opportunities, and informed participation in societal decisions. It allows students to engage with data analysis, fostering a deeper understanding of complex issues such as income inequality, healthcare disparities, and environmental concerns (Frankenstein, 1983).

Thus, social and cultural issues in general as well as groups of individuals with all challenges and problems in the field of teaching and learning, are addressed by mathematics education. Quantitative research also asks questions to find solutions to problems and helps in finding solutions to mathematical social issues.

Mathematical research promotes creating ideas, tools, and techniques critical for improving classroom education (Sriraman & English, 2010). In order to develop evidence-based methods that improve the teaching and learning process, this technique entails modeling and analyzing empirical data. Research in mathematics involves the creation of ideas, ideologies, and values that help in the

prediction of the future. One of the scientific approaches usually used in quantitative research is developing theories, facts, methods, concepts, and hypotheses for the classroom instruction of mathematics (Creswell & Creswell, 2018). It produces instruments, tools, and statistical methods to find manipulated variables and experiment with them in the control group. In quantitative research, empirical data is collected, modeled, and analyzed, and then the result is evaluated. The main objectives of quantitative research are to solve problems and find the results of a large population. Mathematics education uses a whole-stick socio-culturally informed approach and encourages us to engage with and learn mathematics (Sutherland, n. d). One of the most important research projects that quantitative methods in the field of education is establishing new trends of learning adjustments correlated with learning outcomes. Mathematics education is a dynamic subject for computational, statistical, and mathematics instruments. Quantitative research also involves using mathematical, statistical, and computational processes to find the study's objectives. Hence, the two subjects are coherent with each other. The pedagogic aims of quantitative research included student awareness of interdisciplinary research and increased understanding and engagement with issues (Lambe, 2003). This quantitative research helps improve the quality of education and adopt various techniques and methods that can contribute to teaching-learning practice and the professional development of faculties.

## **Method**

The main purpose of this study is to explain the uses and limitations of quantitative research in mathematics education through a research investigation using a literature review technique. The review uses academic databases like Google Scholar, JSTOR, ERIC, and ResearchGate to search for relevant literature on quantitative research in mathematics

education. The search terms used filter out the most relevant studies related to mathematics education and quantitative research. It outlines the scope of the research, identifying key themes such as measurement and comparison, statistical analysis, generality and large-scale studies, effectiveness of teaching strategies, student achievement and impact of intervention.

## **Results and Discussion**

This study aims to provide mathematical knowledge through quantitative research's use, applications, and limits in mathematics education. The researcher has briefly described distinct themes from the different educational databases e.g. ERIC, Proquest, and Google Scholar, published or unpublished studies measuring the objective of this study.

### **Uses of Quantitative Research in Mathematics Education**

A quantitative investigation focuses on post-positive knowledge and uses research methods like surveys and experiments to gather data on established tools that generate statistical data (Creswell, 2008). In mathematics education, quantitative research is utilized to generate statistical data from large numbers of samples to produce statistically valid results. Survey methods are also used to gather data on the opinions of populations in mathematical Education (Cumming & Maxwell, 2015).

Quantitative research is a definitive process model that starts with a theory, generates a hypothesis, tests the hypothesis, and interprets the results (Vanderstoep & Johnston, 2008).

Research in mathematics uses quantitative methods to measure opinions, beliefs, behaviors, and other features, draw conclusions from a broad population, and analyze data using statistical methods. The objective of scientific research is finding rules and

hypotheses that are reasonable for social or natural phenomena or to improve knowledge of science (Bhattacharjee, 2012). Quantitative research is a method used in mathematics education to gather data from large samples using surveys and experiments. This definitive process model starts with a theory, generates a hypothesis, tests it, and interprets the results. It aims to measure opinions, beliefs, and behaviors, draw conclusions, and analyze data using statistical methods, ultimately improving scientific knowledge.

The deductive methods used in quantitative research are unique, considering that they are intended to validate, dispute, or verify existing theories (Robins, 2017). It highlights objectivity and the control of contextual factors that may impact the results. The use of numerical data to explore, describe, explain, or predict the phenomenon of mathematics education. In mathematics education, the emphasis is mainly on creating statistical models and collecting and classifying characteristics (Kothari, 2010). Though the review of literature is a scientific method, it has some uses of mathematics in the field of education. In many academic disciplines, quantitative research is in fact the cornerstone of knowledge development. Quantitative research methods have become essential to scientific investigation because of their emphasis on objectivity, accuracy, and the capacity to generalize findings across groups. Quantitative methods offer essential tools for information acquisition in the existing environment, from guaranteeing reliability of data to permitting causal inference and prediction. Therefore, it is reasonable to claim that quantitative research is the "mother of all knowledge" because it is essential to knowledge creation and the development of scientific methodologies in many fields.

### **Measurement and Comparison**

Quantitative research makes the systematic measurement of educational

outcomes possible, yielding trustworthy data that can be analyzed and compared (Cohen, Manion, & Morrison, 2017). Researchers can compare the performance of various teaching approaches (such as traditional lecture-based vs. inquiry-based learning) and determine which strategies best improve learning by employing particular indicators like student test results or grades. This method also makes it possible to assess educational interventions, like technology-enhanced tools or corrective programs, to see how they affect students' performance in mathematics. Quantitative research is crucial for evaluating student performance, instructional strategies, and learning interventions, particularly in teaching mathematics, enabling comparison of methods, curricula, and interventions' effectiveness. Quantitative research provides the precise evaluation of factors such as student performance, instructional strategies, and interventions for learning. This allows the comparison and evaluation of various methods for teaching mathematics.

### ***Statistical Analysis***

Statistical tools are often used in quantitative education research to investigate the connections between student outcomes and instructional strategies. The level of relationship between the way students' study and their mathematical ability, for example, can be determined using correlation analysis. Regression analysis is a useful tool for assessing how various teaching methods affect student performance. Inferential statistics allow researchers to draw conclusions about the larger population from a sample, which gives them insight into how particular teaching strategies could enhance mathematics learning for different student populations (Field, 2013). ANOVA and t-tests provide group comparisons, supporting evidence-based decision-making within education. It improves difficult statistical analyses, including correlation, regression, and inferential testing.

This supports patterns, connections, and learning improvements in the learning outcomes for achieving mathematical achievement.

### ***Generalizability***

A major goal of quantitative research is to generate findings that are applicable outside of the population under study. To verify that results are applicable to a variety of educational settings, for example, survey-based research or randomized controlled trials (RCTs) involving large numbers of students from various schools or districts are used (Creswell, 2008). Since the efficacy of a teaching strategy or intervention may be assessed on a far broader scale, this is crucial for formulating educational policy. Research on visible learning lends credence to the notion that large-scale, generalizable studies can pinpoint successful teaching methods that enhance student results across several classrooms (Baumann, 1984). The ability to apply study findings to large populations or educational contexts was a goal of quantitative research. This is essential to comprehend the way learning plans or policies affect various students.

### ***Large Scale Studies***

Research with a high sample size can provide a more comprehensive picture of educational trends and patterns while preventing biases or small sample sizes from skewing results (Bryman, 2016). Through different studies, researchers may see how various teaching strategies affect various student groups and learning environments. As an example, policymakers and educators can find best practices in mathematics instruction worldwide by using the Programme for International Student Assessment (PISA), which offers extensive data on mathematical proficiency across nations. With many pupils, it makes to conduct in-depth research and get a thorough understanding of the educational

procedures involved in the teaching of mathematics.

### **Limitation of Quantitative Research in Mathematics Education**

Quantitative research may oversimplify complicated processes by disregarding the particular and depth of individual cases, even while its goal is to generate general explanations and hypotheses (Maxwell, 2013). Quantitative research in mathematics education often overlooks subjective and contextual elements, such as emotional reactions and cultural influences. Standardized tools may oversimplify complex instructional phenomena, highlighting the need for supplementary approaches to address the complex nature of mathematics instruction (Creswell, 2008). Quantitative research's reliance on measurable variables may overlook qualitative data, oversimplify complex phenomena, and overlook individual cases. Its positivist approach may also be limited in studying subjective or socially constructed realities. This research is based on deductive and test theory. Quantitative research is the context of the study based on experiment. It is used in a large sample of the population which must be studied for more accurate results. It directs limited outcomes in the exploration of the outcomes that cannot always represent the actual and repeated measure designs occurring in a generalized form. Quantitative approaches often use large sample sizes, limiting understanding of unique experiences and viewpoints, particularly in mathematics teaching where individual thought processes and problem-solving approaches are crucial (Vanderstoep, 2008).

A process-based approach to data collecting and analysis that generates statistical data may be used by researchers. There are many open secondary data available for quantitative study; however, data should be surveyed critically (Boeren, 2017). The values underlying quantitative research include

neutrality, objectivity, and the acquisition of knowledge. Researchers may employ a process-based approach to data collection and analysis that produces statistical data. Although there are a lot of freely accessible secondary data sets for quantitative research, data should still be thoroughly examined. Quantitative research requires a large sample size in the field of education. There is a wide range of opportunities to use secondary data sets, but survey data has been used with a critical approach in quantitative research (Boeren, 2017). However, due to the lack of resources, this in-depth investigation becomes too vast for managing. The information and resources required to implement or conduct quantitative research may be lacking in several developing countries for interest participants, such as government or non-government organizations, public service providers, educational institutions, etc. Closed-ended questions from a structured questionnaire are tools of quantitative research. The study results in restricted conclusions, which means the results may not accurately reflect the real accumulation in a broader sense. Additionally, the respondents' response options are restricted based on the researcher's selection. The scarcity of resources makes this extensive research difficult. Interest participants may lack information in the majority of developing countries like Nepal. In most developing countries, interest parties may lack information.

Creswell (2008) explained quantitative techniques necessitate complex experiments with variables and treatments that are factorial designs (p.9). Due to the researchers' choices, the respondents' possibilities for answers are limited. An organized questionnaire with carefully planned questions is required for this research. Mathematical research including quantitative methods is challenging, expensive, and time-consuming to do. Careful planning goes into this kind of study to guarantee complete randomization and accurate

designation of the control group (Morgan, 1980). For researchers without skills in statistics, doing the substantial statistical analysis needed for this study might be challenging. Because statistical analysis is grounded in science, non-mathematicians may find it challenging to understand. Quantitative experiments in mathematics research can be time.

### *Effectiveness of Teaching Strategies*

The identification and assessment of successful teaching methods in mathematics education have been greatly aided by quantitative research. For example, research on the effects of problem-solving strategies and the use of technology in the classroom on student learning is frequent. Research has demonstrated that problem-solving techniques promote a deeper comprehension of mathematical ideas in addition to improving critical thinking (Polya, 1945)

The effect of problem-solving techniques or the application of technology in the classroom are two examples of successful mathematical methods of instruction that are often determined by quantitative research.

### *Student Achievement*

The investigation of variables influencing math proficiency among students has also benefited greatly from quantitative research. Studies frequently look at factors including curriculum design, teacher qualities, and socioeconomic position to see how they relate to academic success. Student performance is significantly predicted by instructor certification and experience (Darling-Hammond, 2000). Research emphasizes the necessity for fair access to high-quality education by highlighting achievement gaps based on socioeconomic characteristics (Sirin, 2005). Research on mathematical success levels among students and the influences of

variables including socioeconomic position, teacher credentials, and curriculum design are common. The investigation of variables influencing math proficiency among students has also benefited greatly from quantitative research. Research frequently looks at factors including curriculum design, teacher qualities, and socioeconomic position to see how these relate to academic achievement. The findings give educators and legislators a starting point for tackling structural issues in mathematical education. Mathematics education, quantitative research offers solid statistical support for practice and policy. Researchers aid in the creation of focused instructional practices by identifying successful teaching tactics and interventions. It has been demonstrated that using formative assessments improves student achievement by encouraging adaptive learning and offering timely feedback (Black & Wiliam, 1998). Furthermore, curriculum design and resource allocation are frequently influenced by quantitative findings, guaranteeing that educational policies are supported by empirical data. Policymakers and educators can use these insights as a starting point to address systemic issues in mathematics education.

### **Methodological Consideration**

While quantitative research offers valuable insights, it is essential to consider the methodological limitations associated with these studies. Issues such as sample size, measurement tools, and statistical analysis techniques can impact the validity and generalizability of findings. Small sample sizes may limit the applicability of results to diverse educational contexts (Creswell & Creswell, 2017). Similarly, the reliability of measurement tools, such as standardized tests, is crucial for ensuring accurate data collection. Researchers must also address potential biases in statistical analyses to avoid misleading conclusions.

### **Future Directions**

Researchers suggest further exploration in mathematics education through comparative studies, longitudinal studies, and mixed methods approaches. Comparative studies reveal best practices, long-term effects of interventions, and sustainable improvements, while integrating qualitative insights. The improvement of the mathematics learning results is assessed by quantitative research using educational interventions like academic tutoring and curricular revisions. Scholars find out how quantitative findings affect practice and policy in mathematics education. It is based on statistical proof of its effectiveness and suggests teaching tactics. This section usually includes evaluations of the benefits and limitations of the quantitative techniques used, including sample size, measuring tools, and statistical analysis. Researchers frequently recommend areas for more exploration, such as comparative studies among other educational systems or longitudinal studies to monitor the long-term effects of educational changes.

### **Conclusion**

Quantitative research is the most powerful design for establishing the causal relationship between the dependent and independent variables in mathematics education. Quantitative research aims to create and apply mathematical theories, models, and hypotheses related to phenomena of nature. The basis of knowledge for analytical skills is quantitative research. It would improve our methods of instruction and learning and help societies, educational institutions, and universities create and disseminate information, which causes knowledge to propagate very quickly. It is widely used in many kinds of natural and social disciplines, including journalism, sociology, physics, mathematics, and biology. The process of central measurement in quantitative research establishes the basic link between quantitative connections expressed mathematically and

actual observation. It enables the researcher to measure and analyze data. The results of quantitative research may be applied in various contexts since the sample is representative of the population under investigation in mathematics education and the selection procedure is well-designed. Its data can be very consistent, précised, and reliable. It is relatively easy to analyze in mathematics education. Sometimes, secondary data of quantitative research is not available or available data is problematic. The context of the phenomenon is difficult to understand and infrequently, data may not be compact enough to explain complex issues in mathematics education. So, research is a rigorous activity based on evidence to bring something new or change existing practices. It is the art of scientific investigation and the study of materials and sources to establish facts and reach new conclusions. In conclusion, quantitative research in mathematics education has limits in capturing the complexity and context-specific integrity of educational occurrences, even if it offers valuable insight through careful measurement and statistical analysis. By providing a broader view of mathematics teaching and learning, combining quantitative and qualitative methodologies helps improve comprehension.

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