Understanding Mathematical Difficulties in Students with Dyscalculia: A Mixed Method Investigation

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Abstract:

A research methodology choice, whether quantitative or qualitative has been long standing debate. The quantitative methods offer objectivity while qualitative methods can be subjective. This article focuses on emergence on mixed method research (MMR) integrating both, enhancing the research's credibility, authenticity and generalizability. This article explores the basic MMR designs (Triangulation, Explanatory Embedded, and Exploratory Designs) with criteria of timing, weighting and mixing techniques offering insights into effective design choices. This third paradigm employs triangulation for comprehensive understanding, reducing gaps and ensuring accuracy and Validity. In this paper MMR research design is employed to identify mathematical difficulties of the student with dyscalculia, maintaining a balance between qualitative and quantitative approaches by overcoming the weakness of individual approaches. This article also finds wide application of MMR approach in educational research, effectively addressing complexities in the educational domains.

Keywords: *Dyscalculia, Mixed Method Design/ Research, Qualitative Research, Quantitative Research.*

Abbreviation*: MMR (Mixed Method Research)*

1. Introduction:

Research is pivotal for human development. In today's research arena, researchers need multiple approaches to shape their study more comprehensively and generalizable but a rigid dichotomy between quantitative and qualitative approach bewildered them to follow either qualitatively or quantitatively. For more than a century there has been debates on quantitative and qualitative research paradigm and to resolve such disputes researcher needs to think beyond these two schools of thoughts (Maxwell & Loomis; n.d.)[1]. The quantitative purist believes that social inquiry should be objective, requiring researchers to remove biases and remain emotionally detached while testing hypotheses. Whereas the qualitative purist argue that researchers cannot be detached from their subjects as subjective experience is essential for

[1] Maxwell, J. A., & Loomis, D. M. (n.d.). *Methodological and Analytical Issues. An Alternative Approach: Mixed Methods Design.* (pp. 243-244). Handbook of Mixed Methods in Social and Behavioural Research. https://www.researchgate.net/publication/313552075_Mixed_method_design_An_alternative_approach

understanding reality (Guba & Lincoln; 1994)[2].The difference between these two paradigms is well explained in Table-1.

Table 1: Distinguish Qualitative Research and Quantitative Research

Characteristics	Qualitative	Quantitative
Philosophical Orientation	Interpretive, humanistic and naturalistic	Positivistic
Nature	Subjective	Objective
Design	Flexible & evolving in natural setting.	Structured & Predetermined in artificial setting.
Relationship with Respondents	Close interaction with respondents.	Detached with respondents.
Sampling	Purposive, Theoretical & Non-random	Random, Representative & Large
Analysis	Inductive	Deductive
Findings	Comprehensive, holistic, unique, contextual.	Valid, reliable, reductionist and generalizable.

The purpose of this article to overcome from existent paradigm debate and introduced a new and third paradigm termed as Mixed Method Research (MMR) (Johnson & Onwuegbuzie, 2004)[3]. Emphasizing on any single paradigm cannot give justice to any research issue as open-ended character of the qualitative method reveals excessive subjectivity, whereas closed-ended nature of the quantitative method reveals objectivity (Creswell & Clark; 2011)[4]. Thus, the convergence of qualitative and quantitative methods gives inclusive meaning of any investigation.

1.1 Mixed Method Research "Transformative Paradigm":

An amalgamation of qualitative and quantitative research components award's holistic view of research process, in depth understanding with own philosophical assumptions and different methods of inquiries helps to remove long term paradigm wars (Nastasi, Hitchcock, Sarkar, Varjas & Jayasena; 2007)[5]. This third wave or third research movement represents pragmatic method, integrating both quantitative and qualitative research methods to offer holistic

[2] Guba, E. G., & Lincoln, Y. S. (1994). Competing Paradigms in Qualitative Research. In *Handbook of qualitative research* (Vol. 2, Issue 6, 163-194), (pp. 105-106). https://miguelangelmartinez.net/IMG/pdf/1994_Guba_Lincoln_Paradigms_Quali_Research_chapter.pdf

[3] Johnson, R. B., & Onwuegbuzie, A. J. (2004). Mixed Methods Research: A Research Paradigm Whose Time Has Come. *Educational Researcher*, *33*(7). https://doi.org/10.3102/0013189X033007014 . https://journals.sagepub.com/doi/10.3102/0013189X033007014

[4] Creswell, J. W., & Plano Clark, V. L. (2011). Choosing a mixed methods design. *Designing and conducting mixed methods research*, *2*, 53-106.

[5] Nastasi, B. K., Hitchcock, J., Sarkar, S., Varjas, K., & Jayasena, A. (2007). Mixed Methods in Intervention Research: Theory to Adaptation. *Journal of Mixed Methods Research*, *1*(2), 164–182. https://doi.org/10.1177/1558689806298181). https://journals.sagepub.com/doi/10.1177/1558689806298181

understanding of the study, thus enriching the depth and breadth of the research process (Teddlie & Tashakkori; 2009) [6].

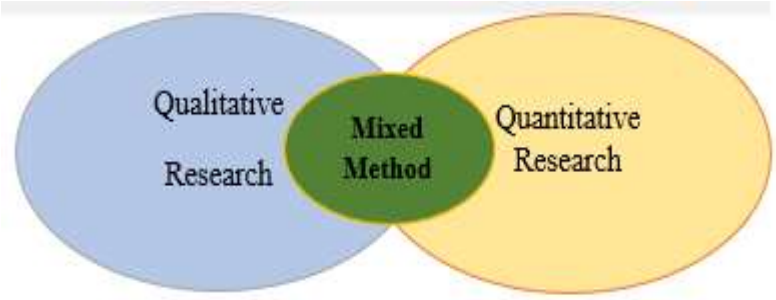

Figure 1: Mixed Method Research

The integration of both methods gives sense of completeness by removing the complexities of phenomenon through triangulation, resulting in reducing the gap in both approaches with full accuracy and high validity (Onwuegbuzie & Leech; 2015)[7]. The major characteristics of MMR by Tashakkori & Teddlie (2012)[8] described below in table 2, help to understand the basic nature of MMR:

Table No. 2: Nine Characteristics of mixed method research
(*Teddlie & Tashakkori, 2012, p. 775*[9])

Quantity of characteristics	Explanation of characteristics	Interpretation of Characteristics
1	*Methodological eclecticism*	Practice of combining various research methods from different paradigms/ approaches.
2	*Paradigm Pluralism*	Acceptance and utilization of multiple research paradigms and perspectives within same study.
3	*Repetitive, cyclical research approach*	Repeating steps of the research process like gathering, analysis, and interpreting data to refine understanding.
4	*Collection of fundamental research designs and analytical methods*	Commonly used or recognized research designs and analytical methods.
5	*Prioritization of research questions or problem in methods selections.*	Importance of aligning research methods with the specific goals and objectives of the research

[6] Teddlie, C., & Tashakkori, A. (2009). *Foundations of mixed methods research: Integrating quantitative and qualitative approaches in the social and behavioral sciences.* Sage Publication. https://in.sagepub.com/en-in/sas/foundations-of-mixed-methods-research/book252072

[7] Onwuegbuzie, A., & Leech, N. (2004). Enhancing the Interpretation of Significant Findings: The Role of Mixed Methods Research. *The Qualitative Report*. https://doi.org/10.46743/2160-3715/2004.1913)

[8] ibid; (footnote-6)

[9] Teddlie, C., & Tashakkori, A. (2012). Common "Core" *Characteristics of Mixed Methods Research: A Review of Critical Issues and Call for Greater Convergence.* American Behavioral Scientist, 56(6). https://doi.org/10.1177/0002764211433795. http://www.ceil-conicet.gov.ar/wp-content/uploads/2015/10/Teddlie.pdf

6	*Focus on continua rather than fixed dichotomies.*	Preference for considering concepts or variables as existing on a spectrum or continuum rather than as binary opposites.
7	*Focus on diversity across all levels of the research endeavour*	Value of incorporating diverse perspective, methods and participants in research activities.
8	*Inclination toward moderation and reconciliation inheritant in the ' third methodological community'*	Inclination towards middle ground or consensus among competing approaches or perspectives in research.
9	*Reliance on visual representation like diagram, figure. Also, a common notational system.*	Communication and understanding among researchers by providing visual aid and standardized symbols or terminology.

1.3 Types of Mixed Method Designs:

Selecting a suitable mixed method design for a study is challenging task, demands expertise and competency. Before knowing the type of design some abbreviations are necessary to acknowledge (Cohen et al., 2018)[10], these are:

QUAN- *Quantitative data emphasize over qualitative data.*
QUAL- *Qualitative data emphasize over quantitative data.*
Quan- *Quantitative data as secondary of qualitative data.*
Qual- *Qualitative data as secondary of quantitative data.*
'+' : Concurrent collection of data.
'→' : Sequential collection of data.
'()' : One method is embedded with another.
'=' : Outcome of the mixing.
→← : Methods used recursively

According to Creswell (2010, p.58-86)[11], the choosing of an MMR design depends on three major factors/decisions, these are:

(1) Timing (sequence/implementation) - of quantitative and qualitative methods either to be used together or one after other.
(2) Weighting (priority/importance) - either quantitative or qualitative in answering the research question.
(3) Mixing (merging/interaction) - the two data sets. The below fig.2 helps the researchers to decide a designing of MMR for their study.

[10] Cohen, L., Lawrence, M., & Morrison, K. (2018). Research Methods in Education. Eighth Edition, (pp. 39-40). In *Research Methods in Education*. Routledge
[11] Ibid; (footnote-4)

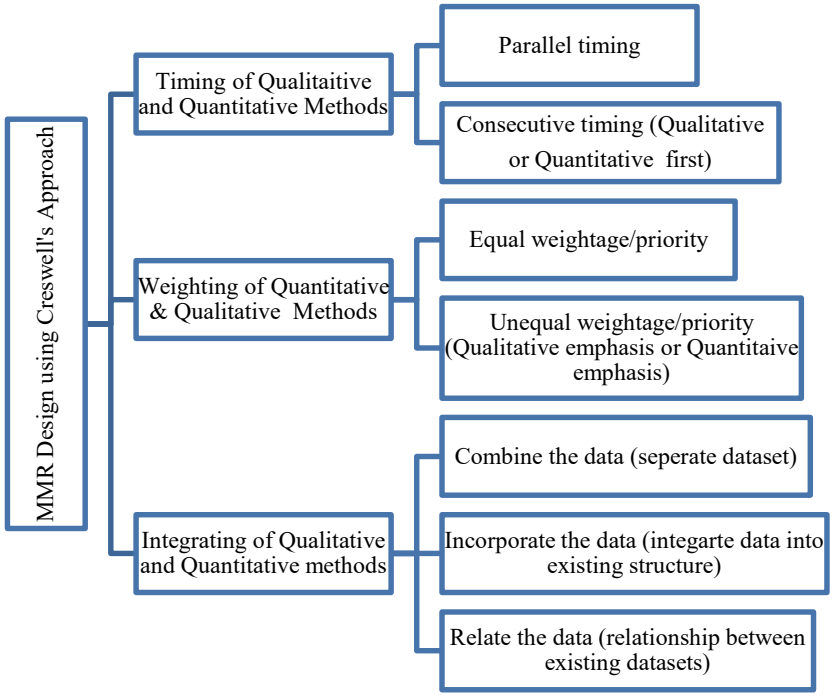

Figure 2: Decision Tree for Mixed Method Design using Creswell's Approach

* *Source: Creswell, 2010, p. 80*[12] (Creswell et al., 2011, p.80)

The below matrix design of mixed method research in four cells, given by Johnson (2004) enable to understand much better the mixed method design and give in- depth insight to any researcher how to collectively decide the design of MMR with the help of fig. 2 and 3. The '+' sign denotes concurrent and '→' denotes sequential, capital letters denote higher priority /weighting and lower letters means less priority/ weighting.

		Time Order Decision	
		Parallel	**Sequential**
PARADIGM EMPHASIS DECISION	Equal Status	QUAL + QUAN	QUAN → QUAL QUAL → QUAN
	Dominant Status	QUAL + quan QUAN + qual	QUAL → quan qual → QUAN QUAN → qual quan → QUAL

Figure 3: Matrix Design of mixed method research

'+' sign denotes parallel , '→' denotes sequential order, uppercase letters denote higher emphasize /weighting while lowercase letters means less emphasize/ weighting.

**Source: MMR designs exhibited in the matrix (Johnson & Onwuegbuzie, 2004, p.22)*[13]

[12] Ibid; (footnote-4)
[13]Ibid; (footnote-3)

The researchers can design mixed method research using a variety of typologies depending on the requirements of the research questions, but the four primary categories of mixed method design are as follows: Designing for triangulation, embedding design, explaining design, and exploratory design (Creswell et al., 2011)[14].

1.3.1 Triangulation Design:

A method that is frequently used by researchers for direct comparison or validation is triangulation, which combines both methods qualitative and quantitative. Overcoming the drawbacks of both methods, its primary goal is to provide a complete understanding of a research topic. Convergence, transformational, multilevel, and quantitative data validation models are four forms of triangulation design (Creswell& Creswell, 2018)[15].

1.3.2 Embedded Design:

The purpose of the embedded design, according to Creswell & Clark (2011), is to combine two datasets in order to enhance the research design. It effectively integrates qualitative and quantitative methodologies to answer topics that cannot be adequately addressed by a single dataset. The Embedded Correlational and Embedded Experimental Models are two forms of embedded design.

1.3.3. Explanatory Design:

There are two stages to the "Explanatory Sequential Design": initial focus on collecting and analysis of quantitative data, followed by collection and analysis of qualitative data. The quantitative approach is given priority, and deeper insights into research phenomena are provided by the qualitative phase design (p. 72-74).

1.3.4. Exploratory Design:

In the "Exploratory Sequential Design," researchers explore a phenomenon qualitatively first, then, using the results, they proceed to a quantitative phase. They seamlessly move from qualitative to quantitative study by using qualitative findings to create instruments or identify variables for testing.

The MMR design is well explained by a researcher conducting a study on mathematical difficulties of the students with dyscalculia using a type of mixed method research.

2. Literature Review

MMR design contributes a significant role in the research of educational domain including special education. Many students exhibit impairment in arithmetic operation, they come under a

[14] Ibid; (footnote-4)

[15] Creswell, J. W., & Creswell, D. (2018). Research Design Qualitative, Quantitative, and Mixed Methods Approaches, 5th Edition. *SAGE Publications Ltd*, *5th Edition. http://www.ceil-conicet.gov.ar/wp-content/uploads/2015/10/Creswell-Cap-10.pdf*

type of specific learning disability termed as dyscalculia. Many studies have been conducted to find the mathematical challenges of the students using MMR approaches. Mundia (2012)[16] employed MMR design in diagnostic testing and interview to find the mathematical challenges of grade 4 students, identifying issues with arithmetic operations, dysgraphia and memory lapses, provide potential cause of math anxiety and dyslexia. Mahmud et al., (2020)[17] emphasized early assessment and intervention of such students as well as highlights the roles of parents and educators in monitoring student's mathematical growth to prevent them from academic and psychosocial issues. Mariera et al,. (2021)[18], evaluated math efficacy of the students with dyscalculia is lower than their non-dyscalculia peers by using MMR approach. Moreover, Tibane et al,. (2024)[19]; revealed significant symptoms of dyscalculia in grade tenth students using qualitative and quantitative approach. Thus, these studies employed mixed method research (MMR) and provided comprehensive insights that enable to design interventions, instructional strategies, and teacher preparation to promote inclusive mathematics education. Moreover, Rights of Persons with Disabilities (RPwD) Act 2016[20] and National Education policy 2020 (NEP 2020)[21] emphasize on the quality education for all irrespective of their backgrounds including disabilities.

2.1 Research Gap:

The above studies followed mixed method research approach. However, apart Mundia (2012), none of the studies explains the mixed method design appropriately. Moreover, studies focus on general mathematical difficulties which may occur from inappropriate teaching process, unfavourable family circumstances, financial difficulties or medical ailments. Thus, existing studies emphasize on mathematical difficulties of general students rather than dyscalculia and lack of suitable type of mixed method design, constituting a significant research gap in this study.

3. Rationale of the Study:

MMR as a paradigm shift, connecting etic and emic research (insider and outsider perspectives) by increasing credibility and pragmatic value of a phenomenon (Mayring; 2007)[22]. The study

[16] Mundia, L. (2012). The Assessment of Math Learning Difficulties in a Primary Grade-4 Child with High Support Needs: Mixed Methods Approach. *International Electronic Journal of Elementary Education*, *4*(2), 347-366. https://files.eric.ed.gov/fulltext/EJ1070446.pdf

[17] Mahmud, M. S., Zainal, M. S., Rosli, R., & Maat, S. M. (2020). Dyscalculia: What We Must Know about Students' Learning Disability in Mathematics. *Universal Journal of Educational Research*, *8*(12B), 8214-8222. Researchgate.net.

[18] Mariera, N. M., Murugami, M., & Muthee, J. (2021). Mathematics efficacy among students with dyscalculia in public high schools in kandara sub-county, muranga county, kenya. *European Journal of Education Studies*, *8*(7). https://oapub.org/edu/index.php/ejes/article/view/3828

[19] Tibane, C. C., Mhlongo, T., & Mafa, T. O. N. (2024). Exploring the Prevalence and Awareness of Dyscalculia Among Grade 10 Learners: A Case Study. https://www.researchsquare.com/article/rs-3884817/v1

[20] The Rights of Person with Disability RPwD) Act ,2016. Last access on 2024 May 15 from: http://www.ccdisabilities.nic.in/sites/default/files/2021-08/RPwDAct2016.pdf

[21] National Education Policy (NEP), 2020. Last Access on 2024 May 15 from: https://www.education.gov.in/sites/upload_files/mhrd/files/NEP_Final_English_0.pdf

[22] Mayring, P. (2007). Mixing Qualitative and Quantitative Methods. In *Mixed Methodology in Psychological Research*. https://doi.org/10.1163/9789087903503_007)

shows multiple justification which encourage MMR as it expands knowledge by combining both quantitative and qualitative research Dawadi, Shrestha & Giri; (2021)[23]. The quantification of data validates results by using p value which help in interpretation and generalization findings with high validity and reliability (Gage; 1989)[24]. But increasing objectivity reduces the subjective nature of study which is compensated by the qualitative mode of research (Hall, 2020)[25]. Thus, the incorporation of both approaches vividly illustrates cause and effect relationships as well as idiographic causal explanation. Cohen et al. (2018)[26] explained that subjectivity and objectivity works at different poles of continua, and they have a different school of thoughts. Subjectivity is interpretive, personal, unreliable, unpredictable, biased, idiographic, and so on. Hence, MMR works on continuum, reduces philosophical contraries, fill the gap of epistemological differences and make a sustainable bridge so that research process become more comprehensive, universal, pragmatic, rational, in view of human and social behaviour (Williams, 2020)[27]. It makes investigation more authentic, effective, refined and well validated by compensating respective weakness of each method with the help of triangulation components (Gillespie et al., 2024)[28]. Moreover, this approach gives holistic view of this study.

4. Objectives of the Study:

(1) To explore the specific mathematical difficulties experienced by students with dyscalculia in understanding of number sense including place value, number comparisons, ascending-descending orders and odd and even numbers.
(2) To investigate the perception of students, special educator, subject teachers and parents to understand the mathematical difficulties faced by the students with dyscalculia.

5. Methodology:

5.1 Data Collection:

The participants in this study are four certified students with dyscalculia (three girls and one boy) of grade sixth and seven, studying in government school of south west Delhi. The two mathematic subject teachers, a special educator and parents of the students are included in this study. The purposive sampling technique is employed in this study.

[23] Dawadi, S., Shrestha, S., & Giri, R. A. (2021). Mixed-Methods Research: A Discussion on its Types, Challenges, and Criticisms. *Journal of Practical Studies in Education*, *2*(2), 25–36. https://doi.org/10.46809/jpse.v2i2.20).
[24] Gage, n.d. (1989). The Paradigm Wars and Their Aftermath A "Historical" Sketch of Research on Teaching Since 1989. *Educational Researcher*, *18*(7). https://doi.org/10.3102/0013189X018007004
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[26] Cohen, L., Lawrence, M., & Morrison, K. (2018). Research Methods in Education. Eighth Edition. In *Research Methods in Education*.
[27] Williams, R. T. (2020). The Paradigm Wars: Is MMR Really a Solution? American Journal of Trade and Policy, 7(3). https://doi.org/10.18034/ajtp.v7i3.507
[28] Gillespie, A., Glăveanu, V., & de Saint Laurent, C. (2024). Mixing Qualitative and Quantitative Methods. In *Pragmatism and Methodology*. https://doi.org/10.1017/9781009031066.007

5.2 Research Design:

This study employed sequential explanatory design, a type of MMR. In this research, both quantitative and qualitative data are employed to triangulate findings. The findings of both quantitative and qualitative were given equal weightage/ priority. The combination of qualitative and quantitative findings helps to identify the mathematical difficulties of students with dyscalculia. Uses of quantitative math test and qualitative data from divergent sources enables to provide a holistic view of this study which helps to design effective intervention plan for these students. The step-by-step process in this study are depicted in figure 4.

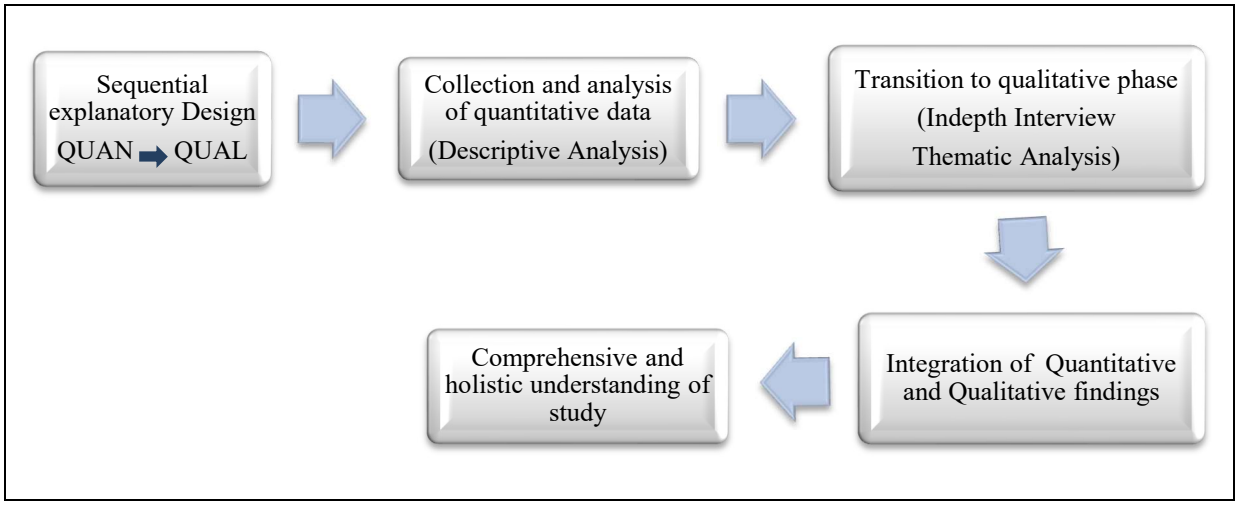


Figure 4: Framework of the Study

*****'QUAN' *denotes quantitative design followed by* 'QUAL' *means qualitative design. Quantitative and qualitative are given same priority/ weighting*

5.3 Research Tools:

i) **Achievement test and Academic Record:** Self-constructed Achievement test was administered on the students with dyscalculia to assess the foundational mathematic skills. The test includes ten questions related to number sense like place value, number comparisons, ascending–descending orders and odd-even numbers. Moreover, the scores of mathematic subjects of these students over the last two years were gathered. This longitudinal data helps to know mathematical abilities of these students.

ii) **Interview**: The semi structured interview was employed by using open-ended questions with special educator, subject teachers, parents and students. Thematic analysis was applied to identify and analyse the emerging themes in qualitative phase.

6. Findings:

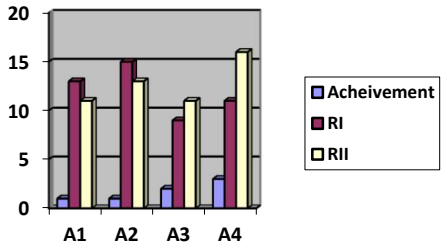
The study consists of two phases, initially start with quantitative phase and followed by qualitative. The findings of both the phases are given below.

6.1 Quantitative Findings:

The self-constructed achievement test was administered on the students with dyscalculia. The findings of one boy (A1) and two girls (A2 and A3) of sixth grade and one girl (A4) of seventh grade are presented in table 3. The scores in achievement test (out of 10) and academic records of two sessions i.e. RI and RII (out of 100) of respective students are mentioned in the table 3.

Table3: Scores of Participants in Achievement Test and School Academic Record

Participants	Scores of Achievement test (10)	Academic Scores of last two sessions (100)	
		2021-22 (R1)	2022-23 (RII)
A1	1	13	11
A2	1	15	13
A3	2	9	11
A4	3	11	16



SPSS 20 is used for statistical analysis. The maximum and minimum scores obtained by the students are mentioned in table 4 having mean in achievement test is 1.75 and scores in both sessions i.e. RI and RII are 12.00 and 12.75 respectively. The maximum scores of the achievement test is 3 which signifies the lack of understanding of number sense based problems among all four students. Moreover, the academic records are very less as per the requirement of the grade sixth and seventh students.

Table 4: Descriptive Statistics of Scores of the Participants

	Achievement Test	RI 2021-22	RII 2022-23
N Valid	4	4	4
Missing	0	0	0
Mean	1.7500	12.0000	12.7500
Median	1.5000	12.0000	12.0000
Std. Deviation	.95743	2.58199	2.36291
Minimum	1.00	9.00	11.00
Maximum	3.00	15.00	16.00

The histogram graphs in the figure 5 give more understanding of the performance of the students. Thus, table 4 and figure 5 assist the researcher to attain insight about the performance of the students and tailor instructional strategies to meet their diverse learning needs.

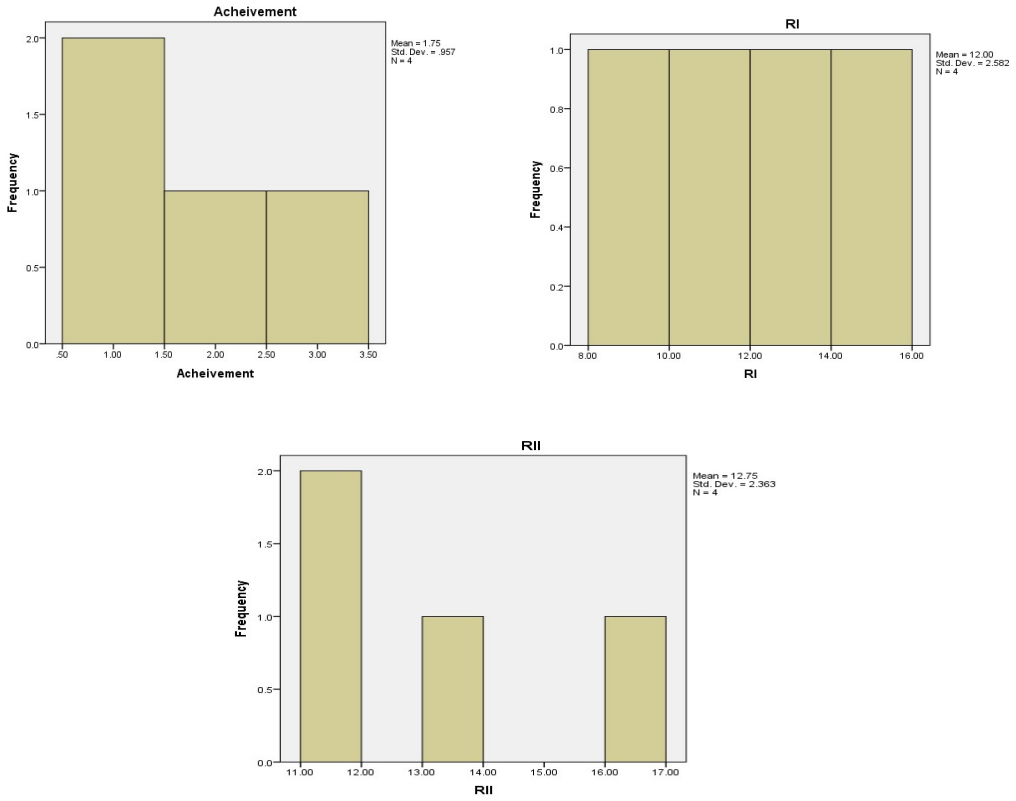


Figure 5: The graphs of the achievement test, academic records of two sessions RI and RII.

To understand much more about the mathematical difficulties of the students, the study follows qualitative findings to give holistic understanding of the respective issue.

6.2. Qualitative Findings:

In this phase, semi structured interview with open ended questions were taken from students, subject teachers, special educators and parents. The major themes come out from this interview are depicted in table 5.

Table 5: Analysis of the Semi Structured Interview

Major Themes	Student	Subject Teachers	Special Educator	Parent
Perceived Challenges and Difficulties	We face difficulties to understand these concepts. We do not know the concepts of place value, number comparisons, ascending–descending orders and odd-even numbers.	These students do not understand the basic numeration, it is difficult to make them understand the abstract concepts.	These students have normal Intelligence Quotients (IQ) but facing issue in academic as their brain are unable to perceive the mathematical concepts.	Our ward having low academic performance, they could not able to assimilate the mathematic concepts that results in lower scores.
Impact on Student	We feel frustrated as we could not understand	They do not concentrate in class	As these students get easily frustrated	They want to avoid to learn

Wellbeing	the concepts. It is very confusing and complicated.	and have no interest in learning.	which lower their self-esteem and may face anxiety when exam comes.	maths, give excuses especially during exam.
Need of Individualized Support	We do not understand what teacher teaches in class. If someone explain more simply maybe, we can understand.	It is difficult to focus individually on them as the class strength is very big and we have to handle the entire class alone. They do not know the basic concepts as well.	There is a need to give them one to one teaching and to know the individual needs of these students.	They may improve if effective instructional strategies will be designed for them as it supports them in learning.

Thus, the findings of both quantitative and qualitative enable to understand the mathematical difficulties of the students with dyscalculia and the results provide comprehensive insights of the need of these students. This result helps to design effective intervention plan for these students where students well beings also need to be focused as it is essential to maintain academic resilience among students for overall growth of the students.

7. Mixed Method Research in Education:

The above study signifies that the amalgamation of both quantitative and qualitative approach makes the learning effective and progressive. MMR is one of its outcomes which has emerged as a result of merging qualitative and quantitative research and plays significant role to counter complexities and interdisciplinary educational challenges (Cohen et al., 2018) [29]. This transformative paradigm is emerging field among scholars which helps to remove debate of paradigm wars in respect to pragmatism (Creswell 2018)[30]. In MMR, research question is often answered by collecting qualitative and quantitative data, opting both types of sampling 'probability and non-probability', using numerical and qualitative tools for data collections where data conversion takes place (either numerical data get qualitied or qualitative data get quantitative) which ensures reliability and high validity through triangulation (Teddlie & Tashakkori, 2009) [31]. –Figure 5 shows the strength of MMR which facilitate educational researchers to investigate educational phenomena.

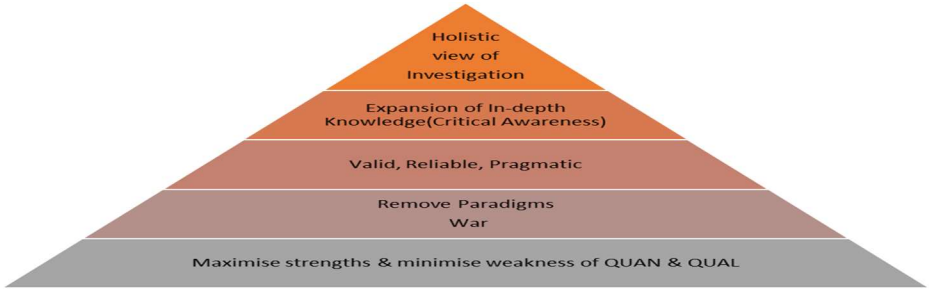


Figure 6: Pyramidal perspective of MMR

[29] Ibid; (footnote-10)
[30] Ibid; (footnote-15)
[31] Ibid; (footnote-6)

Also, it is feasible to implement MMR in Education as it has always been open to alternative methodologies to resolve its several issues and MMR as an eclectic approach focus on the divergent view of educational issues and promoting educational quality (Jick, 1979)[32]. Thus, MMR is revolutionary trend among educational researcher as it is applicable at all stages of research process and dilute the complexities of educational issues.

8. Conclusion:

The purpose of this article is to aware novice researcher about MMR. The convergence of inductive- deductive, objectivity- subjectivity and context- generality features of MMR make it most popular among researchers as it gives comprehensive view of research process by overcoming the weakness of earlier paradigms. It gives deeper insight, offset epistemological differences, and enhance reliability and validity through its triangulation components. Hence, the assorted designs of MMR solve the target research questions and make a study more pragmatic.

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