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Study on Identifying the Lack of Mathematical Competencies Among Secondary School Students Through Diagnostic Tests and Error Analysis

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ABSTRACT
The development of Mathematical Competencies is essential to academic success and real world problem solving. However many secondary school students struggle with foundational mathematical skills leading to poor performance in the subject. This study aims to identify specific gaps in Mathematical Competencies among secondary school students using Diagnostic Testing and Error Analysis. A sample of 40 students from standard IX and X were assessed using a competency-based diagnostic test aligned with curriculum standards. Detailed error analysis was conducted to uncover the patterns of misconceptions, procedures, lapses, conceptual weaknesses etc. The results revealed consistent deficiencies in number operations, algebraic manipulations, geometric reasoning and problem solving strategies. Based on the findings, remedial strategies and instructional adjustments are proposed to address the specified gaps.

KEYWORDS
Mathematical Competencies, Diagnostic Test, Error Analysis

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I. INTRODUCTION

Mathematics is not just a subject, but it is a set of foundational life skills. In a rapidly digitizing world where data, coding, and analytics are becoming the norm, Mathematical Competencies are essential. India is a land of mathematical giants. From Aryabhata's introduction of zero to Ramanujan's mind-bending theorems, the country has given the world some of its most profound mathematical minds. Recently, a declining trend is observed with respect to the level of Mathematical Competencies. According to the Annual Status of Education Report (ASER) 2023, only 43% of Class 8 students could perform basic division. A similar trend was seen in National Achievement Survey (NAS) reports, which highlighted low proficiency even in foundational arithmetic. India's past performance in international assessments like PISA (Programme for International Student Assessment) has been below average. It is the need of time to examine the existing level of Mathematical Competencies among learners at all levels and design frameworks and policies to enhance them. Curriculum and assessment procedures should emphasize on attaining minimal levels of Mathematical Competencies as expected. For this, classrooms should encourage various methods like discussion and problem-solving, not just note-taking. To make math relatable, one may integrate puzzles, logic games, financial literacy, and data science elements into the syllabus. Potential of technology and artificial intelligence might be utilized in all dimensions of Mathematics teaching and learning. Math may be taught through real-life applications, making it relevant and engaging. Beyond all these it is important to ensure that at each level of learning acquisition of required Mathematical Competencies is ensured. Otherwise, gaps in competencies accumulate and hinder with acquiring higher concepts and skills. Incorporating competency based education and appropriate assessment and remediation packages is required to equip the learners with Mathematical Competencies. This will help in retaining the interest in the subject. Scaffolding slow learners with multiple types of content representation and effective diagnostic and error analysis will keep them on track of Mathematics learning and prevent them from withdrawing from the subject.

NEED AND SIGNIFICANCE OF THE STUDY

The academic population is more concerned about Mathematics education than ever before. The reason behind this is the deterioration of quality education with respect to developing competencies and skills in Mathematics. This in fact undermined the foundation of higher education courses in Engineering, Economics and other sciences and commerce subjects. Even though curricula are being updated on a timely basis, effective assessment and remediation of deficiency of Mathematical Competencies is not being emphasized. Hence it is important to study and identify the lack of Mathematical Competencies, especially among secondary school students through diagnostic tests and error analysis. A clear, engaging, and well-structured tone suitable for students lacking fundamental competencies is essential to upgrade Mathematics learning process.

II. CONCEPTUAL OVERVIEW

The concept of Mathematical Competencies has been rooted in Freudenthal's idea of Realistic Mathematics Education. This has evolved through General Mathematical Competencies, German KOM project and framework of Niss and Hojjgard. According to Niss and Jensen (2002) mathematical competence means to have knowledge about, to understand, to exercise, to apply, and to relate to and judge mathematics and mathematical activity in a multitude of contexts that actually do involve, or potentially might involve, mathematics." (p.43). Competence is someone's insightful readiness to act appropriately in response to the challenges of given situations (Niss and Højgaard (2019)). Their framework emphasized that readiness refers to the individual's cognitive prerequisites only, and not to its dispositional, affective, or volitional traits. But in practice the latter is also an essential part of mathematical competence. Following the general definition of competence, Niss and Højgaard (2019) then defined mathematical competence as follows (p. 12): Mathematical competence is someone's insightful readiness to act appropriately in response to all kinds of mathematical challenges pertaining to given situations. Mathematical competencies of the learner help them to mathematize a situation. These are the collective competencies that enable the learner to identify, represent, organize, formulate, seek relationships, seek regularity, model mathematically a real world problem. (Mogens Niss and Tomas Højgaard). Here is a comparison of two major frameworks of Mathematical Competencies

Table 1 Comparison of Frameworks of Mathematical Competencies

Mathematical Competencies	**Ross Turner Framework**	**KOM Germany Project**
STRATEGIC THINKING	Strategic Thinking	Thinking mathematically
X	X	Posing and solving mathematical problems
X	X	Modelling mathematically
MATHEMATICAL REASONING	Reasoning and Argument	Reasoning mathematically
MATHEMATICAL REPRESENTATION	X	Representing mathematical entities
USING SYMBOLIC, FORMAL AND TECHNICAL LANGUAGE OPERATION	Using Symbolic, Formal & Technical Language & Operations	Handling mathematical symbols and formalisms
MATHEMATICAL COMMUNICATION	Communication	Communicating in, with, and about mathematics
X	X	Making use of aids and tools (IT included)
X	Mathematising	X
MATHEMATICAL CONNECTION	X	X
ARGUMENTING / GIVING PROOF	X	X

LITERATURE REVIEWED

Mathematical Competencies, according to the PISA framework include not only content knowledge but also the ability to apply mathematical reasoning and problem solving in real life context. Diagnostic assessment is used to identify student strengths and weaknesses before instruction begins. It informs teachers about specific areas of conceptual or procedural difficulty. Blake and Williams (2010) defines diagnostic testing as identifying learning difficulties through tests in order to provide targeted remedial instruction to help students overcome those difficulties. Diagnostic tests are aimed at locating specific learning deficiencies in students to address through remedial teaching. Error Analysis examines students' incorrect reasoning to understand their misconceptions and their faulty reasoning. Error analysis is the process of examining students' work to understand the reasons behind their incorrect solutions. It involves identifying patterns in errors, analyzing the underlying misconceptions or skill deficits, and using this information to adjust teaching strategies. According to Ashlock (2010), categorising and interpreting errors can guide remediation. This approach helps teachers diagnose areas of difficulty and provide targeted support to improve student learning. Error analysis is a diagnostic tool that helps teachers move beyond simply identifying incorrect answers and towards understanding the learning process of each student.

Téglási (2010) examined Mathematical Competences in Secondary School Students. Based on PISA frameworks, this paper analyzed competence-based education versus traditional methods. Students completed tasks requiring various skills beyond rote learning. The study highlights gaps in applied problem-solving and proposes tailored developmental strategies. This study attempted to reconcile traditional and competency-based evaluation. By comparing student performance on conventional tests and competence-oriented assessments, it exposed how standard exams may not fully reflect students' applied mathematical abilities. This underlines the broader issue across studies: measurement tools significantly influence how we perceive and cultivate mathematical competence. Student-focused studies illustrated a spectrum of competency levels across age groups and disciplines. Xu et al. (2023) proposed a hierarchical model of mathematical skills, showing how foundational numeracy supports more complex abilities such as algebra. This tiered progression was echoed in the SUKEN test-based study by Jaikla et al. (2021), where many students could not conceptualize unit relationships, highlighting weaknesses in spatial and dimensional reasoning. In their study of 139 students Jaikla et. al. used the SUKEN proficiency test. Only 17.27% passed the minimum threshold. Significant difficulties were observed in unit conversion tasks (e.g., cm^3 to m^3), suggesting a need for geometric modeling to improve understanding of volume and dimensional analysis. Evaluation of Math Competence in First-Year Economics Students in Poland (Kopańska-Bródka et al., 2015) tracked the math skills of first-year economics students from 2012–2014, following the reintroduction of compulsory math exams in Poland. It revealed persistent gaps in basic knowledge and calculation skills, despite formal testing, emphasizing the challenge of translating exam success into practical competence. Teacher-focused studies (Bozkuş & Özgeldi, 2024; Carbonero Aguilar & Farías Ortíz, 2024) emphasized how instructors both embody and transmit mathematical skills. While most teachers demonstrated high proficiency in symbolic manipulation and ICT integration, they struggled with fostering higher-order competencies like representation and reasoning in students. Teachers' perspectives strongly influenced which strategies—like argumentation or contextualized problem-solving—were used to build competencies in the classroom. High school and undergraduate evaluations (Delgado Torres, 2020; Hidalgo et al., 2018; Kopańska-Bródka et al., 2015) revealed a worrying disconnect: students often performed poorly in applied problem-solving despite passing formal assessments. This was attributed to traditional pedagogy that prioritized memorization over deep conceptual understanding. In Peru and Poland, despite standardized curricula and testing reforms, many students lacked confidence and fluency in using mathematical reasoning to solve real-world problems. The role of educational transitions such as entering teacher training or engineering programs—was explored in studies like Mamani Callacondo (2018) and Gocheva-Ilieva et al. (2020). While students entering higher education often had basic mathematical fluency, complex competencies like modeling and argumentative reasoning were underdeveloped. These gaps necessitate more integrated pedagogical approaches, combining theory with practice and leveraging diverse tools for teaching-learning and academic assessment.

Collectively, these studies emphasize that mathematical competence is a layered, multifaceted domain influenced by both teaching practices and assessment methods. Mathematical competencies are multidimensional constructs involving not just procedural fluency but also reasoning, representation, connection, and communication. These competencies are crucial not only for academic success but also for professional readiness in STEM and non-STEM fields. Among secondary school students while foundational skills are often in place, higher-order competencies such as reasoning, representation, and strategic thinking remain underdeveloped. Bridging this gap will require rethinking both curriculum, pedagogy and remedial programmes — shifting from summative evaluation to real-time diagnosis and rectification of errors made by students as part of the learning process.

OBJECTIVES OF THE STUDY

1. To identify the specific Mathematical Competencies lacking among Secondary School Students
2. To analyse the types and causes of errors made in Mathematical Problem Solving
3. To suggest the remedial teaching strategies based on diagnostic test and error patterns

III. METHODOLOGY

The study follows a descriptive diagnostic research design using quantitative and qualitative data from diagnostic testing and error analysis. A sample of 40 students were selected from IX th and X th standards of Sree Sankara Oriental Higher Secondary School using stratified random sampling. The diagnostic test contained 43 items. This was developed aligned with core Mathematical Competencies from the content Algebraic manipulations, Basic Coordinate Geometry and Number Sequences. The items focused on fundamental Mathematical Competencies like Communication, Connection, Representation, Using Symbolic Formal and Technical Language operations and Strategic Thinking. The test was validated by experts in Mathematics education. The diagnostic test was administered to students under standard conditions. The responses were coded and scored according to a predefined framework. Incorrect responses were analysed using an error coding framework. The students were classified into three groups namely Below Average , Average, Above Average by finding the mean and Standard Deviation of the score. Incorrect responses were analysed in detail and percentage analysis was done. A percentage analysis was used to find the extent of deficit of each Mathematical Competency and their respective sub-competencies..

ANALYSIS AND INTERPRETATION

The level of Mathematical Competencies of the selected students were examined using the measure of mean and standard deviation. The scores of 40 students were analysed. Mean was found to be 10.61 with a Standard Deviation (SD) of 6.33.

Table 2 Classification based on Mean and Standard Deviation

	Below Average (G1)	**Average (G2)**	**Above Average (G3)**
	Score ≤4.28	4.28 ≤ Score ≤ 16.9	Score ≥ 16.9
No. of Students	6	26	8

Table 2 reveals that students were classified into three groups using the mean value and standard deviation measures. The group of 40 students were classified as Below Average (Score ≤4.28), Average (4.28 ≤ Score ≤ 16.9) and Above Average (Score ≥ 16.9). Eight students were found to be Below Average while six of the students performed at Above Average level. The remaining 26 students performed at Average level in the diagnostic test. The Mathematical Competencies used and those deficient were analysed and listed groupwise.

Table 3 Competency based Percentage Analysis

	MCM (7)		**MCN (8)**		**MRP (8)**		**SFT (5)**		**ST (8)**	
	Sub-Competencies Observed	Percentage of Competency used	Sub-Competencies Observed	Percentage of Competency used	Sub-Competencies Observed	Percentage of Competency used	Sub-Competencies Observed	Percentage of Competency used	Sub-Competencies Observed	Percentage of Competency used
G 1	Reading	14.3	Recognise	12.5	Verbal	12.5	NIL	0	NIL	0
G 2	Reading	14.3	Recognise	12.5	Verbal	12.5	Symbolic Expression	20	Observe	12.5
G 3	Reading, Decoding,Interpreting	42.9	Recognise, Interconnect	25	Verbal, Symbolic	25	Symbolic Expression, Convention	40	Use, Observe, Manipulate	37.5

Table 3 reveals the extent to which selected competencies were demonstrated by the three groups. The students of G1 group exhibited 14.3 % of MCM and 12.5% of MCN. The competencies of SFT and ST were not at all used. The G2 group used 14.3, 12.5, 12.5, 20 and 12.5 percentages of the competencies MCM, MCN, MRP, ST and SFT respectively. The G3 group possessed more competencies namely 42.9% of MCM,25% of MCN, 25% of MRP, 40% of SFT and 37.5% of ST

Interpretation

From these tables the G1 group could read and communicate the task given. They recognised the concept of algebra behind the questions. They were unaware of any kind of graphical representation. G1 group was deficient with respect to many sub competencies like Decoding, Interpreting, Explaining, Presenting, Arguing, Demonstrating, Apply , Derive, Analyse and the competency of Strategic Thinking. They were less familiar with Symbolic Expressions and Algebraic Conventions.

The G2 group demonstrated more competencies than the G1 group. They could Interconnect concepts, Identify the two dimensional graph and observe patterns in number sequences. Yet they were incapable of finding a strategy to Evaluate the arithmetic problem without using a calculator. They could not Decode and Interpret simple verbal mathematical statements into algebraic statements.

The G3 group performed beyond the average students. They could Read, Decode, Interpret, Recognise and Interconnect the mathematical concepts involved in the test. They were familiar with symbolic expressions and algebraic conventions. They could switch from verbal to symbolic representations. They used their previous connections, observed the number patterns and manipulated them to solve the given problem. But they could not distinguish and classify certain numbers (eg. negative real numbers, integers). They could not Interconnect Graphical and Algebraic Representations. They could not Derive numerical representation from verbal or algebraic one.

There is a significant gap between the projected level of Mathematical Competencies and the actual values. This may be due to the reason that at lower stages of education the instruction procedure did not account to remediation. The instruction might not have included various representations of the same concept. Maybe there was no provision to check or assess the students in a formative way. The summative assessment scores were not the true indicators of the actual academic level of the student.

IV. FINDINGS

The selected sample of 40 students demonstrated only a few of the essential Mathematical Competencies. Of the critical competencies, Strategic Thinking was not at all used by students of all three groups. Out of the sub-competencies, reading and recognition were observed while ability to derive, apply, represent and think strategically were not observed among students. They possessed only a small percentage of competencies required to solve the problems in the diagnostic test. A timely remediation at the lower levels and the current level of education could have cleared the gap in the required Mathematical Competencies. Even though the test had the scope to utilize interpreting, arguing, demonstrating, geometrical representation, problem solving, differentiating and manipulating, students could not use them to arrive at the solutions. Some of them could not even identify and recognise the concepts behind. It is extremely important to rectify this deficiency by giving sufficient remedial instructions to compensate for the deficit. Such a remediation may be done at the entry level as a prerequisite or remediation may support classroom instruction for real time error analysis.

V. SUGGESTIONS

To improve the mathematical competencies of secondary school students, diagnostic testing and error analysis can play a pivotal role within the framework of formative assessment. Diagnostic tests help identify specific learning difficulties, misconceptions, or gaps in prerequisite knowledge before or during the instructional process.Diagnostic results should inform curricular teaching especially in algebra and problem solving competencies. By carefully analyzing students' errors, what is wrong, why it is wrong, teachers gain deep insights into their conceptual misunderstandings and procedural lapses. This error analysis allows for targeted interventions, where instruction can be tailored to address individual or group needs effectively. Rather than merely focusing on scores, formative diagnostic assessments create a feedback loop that supports ongoing learning and growth. When used consistently, these practices enable teachers to adapt their pedagogy, provide timely remedial instruction, and ultimately enhance students' problem-solving ability, reasoning, and confidence in mathematics. Remedial instruction may be given in such a way to ensure that the student acquires the required competencies. This may include visual models, scaffolding products like step-by-step worksheets. Outcomes of instructional and remedial programs should be competency based. Teachers may be trained to design and interpret diagnostic tests, conduct real time error analysis during instruction. The diagnostic, error analysis and remedial measures should align with existing curricula. Curricular objectives may be reorganised in terms of major Mathematical Competencies.

VI. CONCLUSION

There is a situation seeking immediate attention to enhance the achievement level of school students as pointed out by various studies and surveys (NAS 2021, ASER 2023 etc.) Various programs like special coaching are being given to students of IX^{th} grade who scored below average. But the assessment procedure is unable to identify the level of foundational Mathematical Competencies. At most of the levels of education, lack of competencies are not diagnosed and remediated. These lapses are carried forward to higher levels of education as well as to the field of career and job opportunities. If suitable remedial programs are designed to replenish the deficient competencies, students will have improved career and job opportunities. There exists a serious lack of competencies among a large group of student population. Also, in the higher education sector as well as secondary schools, there is a tendency to avoid Math related subjects and combinations. This trend should be reversed which would otherwise create a generation of non-competent workforce. Curricular reforms giving due emphasis on real-time diagnosis and error analysis may be helpful in integrating Mathematical Competencies in a better way.

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