

Misconceptions of 10th Graders about the Concept of Equality in Mathematics: Prevalence and Gender-Based Differences

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Abstract

This research explored the conceptions of Grade 10 students on the concept of equality in mathematics and explored possible gender-based difference. Quantitative descriptive-comparative research design was used, with a population of 1,000 students in the secondary schools of the public as a sample chosen using proportional stratified random sampling. The Questionnaire on Equality Symbol (QES) was used to collect data by evaluating the comprehension of students regarding the definition, properties and application of equality. The results showed that students displayed moderate levels of knowledge generally, and the most problems were observed with comprehending the properties of equality, whereas their ability to understand definitions and be able to apply them was relatively high. Gender analysis showed that there were minimal differences between male and female students which were not significant. These findings point to the necessity of instructional plans centered on reinforcing the conceptual knowledge, using the visual and context representations, and incorporating the student-centered methods. In addition, the assessment practices are supposed to be focused on reasoning and application to detect misconceptions, and the development of teacher professionals should be aimed at effective techniques to teach abstract mathematical ideas. These strategies will help make students more competent in their reasoning about equality, their ability to solve problems, and their abilities in reasoning about mathematics.

Keywords: Equality Concept, Misconceptions, Grade 10 Students, Mathematics Education, Gender Differences

Background of the Study

Mathematics is an essential science that is key in shaping reasoning capabilities, problem-solving skills, and capabilities of thinking logically to pursue education and be part of the contemporary society. At the core of learning mathematics is the notion of equality which is the basis of arithmetic operations, algebra, and mathematical modeling. Equality helps learners to learn about balance, equivalence and relationship among quantities, which is the foundation of solving equations and thinking functions. In modern contexts of mathematics education research, it is emphasized that a rich conceptual grasp of equality is crucial to the development of mathematics coherently, especially in the process of senior secondary education students as they transition to

relational thinking (Tobias et al., 2018). Equal sign as an indicator of an answer the idea of equality in mathematics goes beyond the use of the equal sign as a way of showing the answer. Rather it is a relational symbol which means the equivalence of two expressions. Empirical research, however, shows that a good proportion of students are of an operational conception of equality, and they understand the equal sign as an imperative to do a calculation instead of a relation of equality. Misperceptions in this case usually start in lower school-going years and continue to later years unless the meaning of relationships are specifically taught. A recent study points out that students with operational conceptions of equality have difficulties forming algebraic competence and commit a pattern of chronic mistakes in solving equations (Ran et al., 2023). In Grade 10, students are supposed to use the understanding of equality in various areas of mathematics, such as linear and quadratic equations, algebraic manipulation, and problems involving the use of symbols to solve them. At this level, the illusions regarding equality may be a major factor that impedes the capacity of the students to interact meaningfully with algebra and advanced mathematics. Research studies at the secondary education level indicate that learners who have poor relational conceptualization of equality are more likely to use rote procedures and frequently apply rules without a grasp of the mathematical relationships within them, which leads to negative academic outcomes and lack of confidence in mathematics (Fyfe and Rittle-Johnson, 2017). Misconceptions in mathematics have since been clearly perceived as highly grounded alternative conceptions as opposed to errors or ignorance. With equality, the misconception can be the definition of equality, the properties of equality or the use of equality in mathematical metamorphoses. According to research, such misconceptions are so stubborn to change since they are consolidated through repetitive practice of procedures and constrained conceptual deliberation in classrooms. To overcome such a misunderstanding, it should be instructed through purposeful measures that encourage conceptual warfare and critical thinking, especially when it comes to abstract issues like equality (Schiff, 2015).

Differences in learning mathematics between males and females have been among the longstanding research topics in education, specifically, in the areas of achievement, attitude, and cognitive strategies. Although the gender gaps in the large-scale assessments tend to decrease in terms of the overall mathematics performance, they might persist in particular areas of concepts and errors. According to the latest researches, male and female pupils might also have a difference in processing symbolic representations and conceptual relationships, which might impact the nature and the number of mistakes that they make in mathematics (Martynovsky, 2021). Gender differences in mathematical knowledge are also caused by sociocultural and classroom-related factors. Students may be influenced by the instructional practices, teachers' expectations, peer relations and the societal ideas regarding gender and mathematics. Studies that have been carried out in the secondary school remarks that gendered learning experiences can influence the levels of confidence and readiness to interact with abstraction, like equality, and thus shape the continuation of misconceptions (Andersen and Smith, 2024). Although research on conception of equality among students has been conducted widely, most of the literature available concentrates on primary students or lower-secondary students with relatively less studies being conducted on misconception of equality among upper-secondary students. Grade 10 is a critical period when mathematical thinking among the students is getting more formal and any misconception that is not being resolved may have a long-term effect on the learning of advanced mathematics. The current summaries of mathematics education research note that diagnostic studies at this tier are necessary in order to discover deeply ingrained misunderstandings not necessarily reflected by achievement scores alone (Krasa et al., 2022).

Moreover, despite the long-standing research on gender differences in mathematics performance, there is still no intensive studies that focus on gender-varied differences in misconceptions of most

basic mathematical principles like equality. It is necessary to learn about the prevalence and the nature of those misconceptions amongst the Grade 10 students and their potential gender differences to inform the equitable teaching practices. Recent studies promote specific conceptual studies to facilitate targeted interventions and curriculum development to enhance conceptual knowledge of every learner (Siyepu, 2015). With mathematics education changes nowadays, that favor conceptual knowledge and reasoning, this study aims at investigating the misconceptions about the concept of equality among Grade 10 students with interest in their rates and possible gender disparity. This research will help in enhancing mathematics teaching, their assessment, design at the high school level and eventually achieve improved and more equitable learning outcomes in mathematics by creating empirical evidence of conceptual challenges students face during learning.

Rationale for the Study

Secondary mathematics and especially algebra are based on the notion of equality, and the fact that a good number of Grade 10 students still harbor various misconceptions, which inhibit their comprehension of equations and symbolic thinking. This is an important concern that should be tackled at upper-secondary level since continuous operational definitions of equality can cause systematic errors and restrain the willingness of students to take up higher mathematics. Grade 10 is a critical phase during which illusions in case they are not investigated can become deeply-rooted and are mostly ignored by achievement-based tests. Although of importance, there has been scant studies that have specifically addressed the prevalence and nature of equality related misconceptions among students at this level and in particular and formal algebraic situations. The analysis of the gender-based differences also supports the reasoning behind the present research since the conceptual knowledge and error patterns could be different even within the context of achieving the narrowing gaps. The recognition of such differences could be used as a foundation in designing instruction to be delivered in a fair and focused way. On the whole, the present research is justified to present empirical data that could legitimize the concept-oriented instruction, enhance diagnostic evaluation and student relational conceptualization of equality in the secondary level mathematics.

Statement of the Problem

Mathematical reasoning and algebraic thinking are based on the idea of equality; nevertheless, a number of Grade 10 students portray the same concept with consistent misconceptions concerning its meaning and application. Rather than perceiving equality as an inter-relational concept meaning equivalence between two expressions, students tend to see the equal sign operationally as a command to find an answer. These myths result in repeated mistakes of algebraic manipulation and equation solving that restricts conceptual learning and achievement in secondary mathematics. Although such a notion is significant in terms of the upper-secondary level, few empirical studies have been conducted to explore the level of equality-related misconceptions among Grade 10 students. Additionally, conventional tests are more likely to focus on the accuracy of procedures that can mask underlying conceptual misconception. Moreover, they did not pay enough attention to the possible gender-based distinctions in the misconceptions regarding equality among students. Lack of such evidence limits the process of designing focused and fair instructional methods. Hence, effective mathematics teaching and learning requires a systematic study of the high frequency of misconceptions on the concept of equality among Grade 10 students, and how well these misconceptions vary according to gender.

Objectives of the Study

1. Identify the degree of misperceptions amongst Grade 10 students on the concept of equality in mathematics.
2. Compare the misperceptions associated with the concept of equality between Grade 10 male and female students.

Research Questions

1. How common are the misconception about the concept of equality in Mathematics amongst Grade 10 students?
2. Do male and female Grade 10 students have any major differences in the misconception about the concept of equality?

Review of Literature

It is important that students should learn the basic principles of algebra, including mathematical equality in order to succeed in high school mathematics. Misconceptions on the equal sign and the relationship concept of equivalence have been common in mathematics education research, with most learners regarding “=” as a calculator instructional operation rather than as a relational signifier that the two expressions have the same amount. Such interpretation of operations prevents students to move to a formal algebraic thinking and may strengthen superficial procedural modes of solving equations (Ardiansari, Suryadi & Dasari, 2023). Algebraic misunderstandings are not confined to arithmetic only but are also evident in the higher level of mathematics where students have a poor understanding of fundamental concepts, especially variables and equality, among others, and this fact hinders their capability to solve algebraic equations and to interpret algebraic expressions. An overview of the conceptual literature notes that the most tenacious myths in K-12 algebra have been related to the issues of equality and variable representation, and calls on the further development of instructional innovation to improve the conceptual basis of the students (Obot and Delavari, 2025).

Misconception relating to equality is not kept in early grades only but is also applicable in schooling. The studies involving young learners demonstrate that despite the ability to do arithmetic operations, students do not apply relational strategies to comprehend equivalence statements and instead rely on simplistic operational reasoning (McAuliffe, Tambara and Simsek, 2020). These results highlight the fact that unless the relational sense of equality is explicitly focused on, students might bring limited senses to their higher stages of learning mathematics when flexibility and the ability to integrate concepts are demanded. Along with the conceptual misconceptions, the student errors and misconceptions in algebra in general are sources of learning problems in secondary mathematics. The analysis of the mistakes in algebra done by secondary school students has revealed that the root cause of the errors is the weak conceptualization of algebraic structures (including variables and relationships) and that the traditional model of instructions might not be particularly effective in overcoming deep-seated cognitive barriers to algebraic reasoning (Mulaudzi, 2024). The study of math misconceptions and teacher preparedness suggests that teacher awareness to misconceptions among the students- and their capacity to solve them- is a key element of a successful teaching. Research indicates that the knowledge that new teachers have about mathematical misconceptions is a strong predictor of their ability to detect and correct misconceptions of students, which implies that professional development must also involve intensive training in conceptual diagnostic skills (Uygun et al., 2024). This may also be the case between self-concept and affective aspects of mathematics learning in the unequal development of conceptual understanding. Gender studies have indicated that boys and girls may have varied performances in terms of mathematics self-concept and performance. As an example, longitudinal

data show that the role of judgments by the teachers and perceived teacher judgments by students are involved in the formation of gender differences in mathematics self-concept, the latter are frequently held by boys regardless of their performance (Reschke, Steinmayr & Spinath, 2023). Gender stereotypes in mathematics have also been associated with the larger misconceptions and belief systems regarding ability and performance. The conceptual models of analyses of the gender myths in mathematics reveal that the misconceptions are widespread, including that boys are naturally better at mathematics or that girls counterbalance this by trying harder instead of being naturally gifted and thus, failing to discover their interest in math tasks (Dersch, Heyder and Eitel, 2025). Recent efforts also mention the moderating effect of instructional context in gender differences in mathematics. Cooperative instruction and active learning strategies were found to boost the performance of girls in mathematics and minimize gender disparities, and classroom practices have served as the possible lever to tackle the gendered gap in the conceptual knowledge (D'Ignazio et al., 2024). The gender perception is also projected to other social settings like the teacher conduct and classroom contents. Studies on teacher awareness of stereotypes reinforcing behaviors demonstrate that teacher behavior could unwillingly pass on math gender stereotypes, i.e. teacher cognition and lesson decisions may unwillingly reinforce gender patterns in student conceptual growth (Nurlu, 2025). Though a significant part of the gender research is based on achievement and attitudes, these results indicate that the gendered influences can influence conceptual learning indirectly, by influencing the beliefs of students regarding mathematics, their confidence and their interaction with such important concepts as equivalence and algebraic reasoning. The recorded relations between gender stereotypes, self-concept, and mathematics performance underscore the importance of putting into consideration the sociocultural context where the conceptual misunderstandings such as those regarding the concept of equality are investigated (Yan, 2024). Taken together, this body of literature indicates the existence of the misconception about equality and algebraic concepts at educational levels and can imply that cognitive and sociocultural aspects such as gender beliefs and teacher practice contribute to the development of these misconceptions. Nevertheless, a large gap still exists in any empirical research that specifically looks at misconceptions in the idea of equality by Grade 10 students and the way these differ in terms of gender primarily in the context of upper secondary schools where algebraic thinking is the focus of mathematics. This difference demonstrates the necessity to conduct specific research on how often these misconceptions occur as well as the possible gender-based variance to support the implementation of specific, fair instructional interventions.

Research Methodology

This research was a quantitative descriptive-comparative study, which aimed to analyze the popularity of the stereotypes related to the concept of equality among students of Grade 10, as well as analyze whether there are any gender-specific differences. The descriptive aspect made it possible to systematically identify and quantify the misconceptions, whereas the comparative aspect made it possible to analyze the discrepancies between male and female students. This was a good design as it offers objective, numerical data without manipulating any variable, which is easier to conduct prevalence evaluation and compare genders (Creswell and Creswell, 2023). The study population was all the public secondary schools in District Gujrat which included total 265 schools of which 128 were female schools and 137 were male schools. The population accessible was comprised of all of the public secondary schools of Tehsil Gujrat of District Gujrat. As a result of practical limitations to reach all schools, Proportional Stratified Random Sampling has been used. The population was classified into two groups: male and female schools and 15 percent of schools in each group was randomly chosen. The study sample was 20 public secondary schools, 9 schools of female sex, and 11 schools of male sex. A random sample of 50 students will be

selected in every chosen school, and this makes a total sample of 1,000 students (550 males and 450 females). This method guaranteed that the proportions between the female and male students were balanced and made data collection viable.

Instrumentation

In this quantitative research, data were collected through a structured questionnaire known as Questionnaire on Equality Symbol (QES) which was actually created to determine the misconception of Grade 10 students concerning the concept of equality. The questionnaire contained questions that were in three important areas namely; the definition of equality, the properties of equality and the application of equality in arithmetic and algebraic situations. All questions were multiple-choice, and distractors were created deliberately to distribute the possible misconceptions previously found in the prior studies (Ardiansari et al., 2023; Obot and Delavari, 2025). It has been confirmed by mathematics education professionals to be content relevant and straightforward and was pilot-tested on a limited set of students with a Cronbach alpha of 0.82 which is a satisfactory degree of reliability.

Data Collection

In this study, data was collected following the school authority permission and student and parent informed consent. The Questionnaire on Equality Symbol (QES) was conducted on a classroom condition, and under standardized conditions, and the instructions were given to the respondents clearly by the researcher. The students were provided with enough time to fill in the questionnaire on their own with no assistance so that the answers were based on their genuine knowledge. The data collected were then verified as complete and ready to be analyzed statistically keeping the confidentiality and anonymity of all respondents.

Data Analysis

Table 1: Students' conceptions about the definition, Properties and Application of equality

Variable	N	Mean	SD
Definition of Equality	1000	3.03	1.43
Properties of Equality	1000	2.30	1.44
Application of Equality	1000	2.96	1.41

Table 1 shows the conceptual views of the students on the topic of equality in three areas, namely definition, properties and application. The findings suggest that the students had moderate level of knowledge on the meaning of equality (Mean = 3.03, SD = 1.43) meaning that although a good number of students were able to comprehend the fundamental meaning, there was a high degree of deviation in understanding. Conversely, the properties of equality were the most difficult to comprehend as the mean score was 2.30 (SD = 1.44), meaning that students were unable to grasp the most important properties such as the reflexivity, symmetry, and transitivity. In application of equality, the students demonstrated moderately low skills (Mean = 2.96, SD = 1.41) which can be attributed to problems in correctly applying equality concepts to arithmetic and algebraic problems. On the whole, the results indicate that the comprehension of equality among students is disproportionate, and the weaknesses are noted in the areas of conceptualizing its properties, which also promotes targeting the instructional interventions to improve these aspects.

Table 2: Students' Conceptions about the Definition, Properties, and Application of Equality (by Gender)

Variable	Gender	N	Mean (%)	SD (%)
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Definition of Equality	Female	450	3.03	1.44
	Male	550	3.03	1.42
Properties of Equality	Female	450	3.02	1.41
	Male	550	2.98	1.45
Application of Equality	Female	450	2.90	1.37
	Male	550	3.00	1.43

Table 2 displays the notion of equality among the students regarding the three domains including definition, properties, and application broken by gender. Regarding the definition of equality, there were no gender differences in the understanding of the basic concept because both female (Mean = 3.03, SD = 1.44) and male students (Mean = 3.03, SD = 1.42) showed equal levels of understanding the vision. Concerning the properties of equality, female students scored slightly above the male students (Mean = 3.02, SD = 1.41) indicating that they have a small edge in conceptualizing the major properties of equality, including reflexivity, symmetry, and transitivity. Male students scored a little higher on the application of equality (Mean = 3.00, SD = 1.43) than females (Mean = 2.90, SD = 1.37) as the difference of scores is not very significant between males and females. In general, the findings indicate that there are few gender differences in the knowledge of students on equality, and both male and female students are moderately cognizant in all areas, although there are small differences in certain areas.

Table 3: Difference between male and female students' conceptions about the concept of definition, properties and application of the equality

Variable	Gender	N	Mean	SD	df	t-value	p-value
Definition of Equality	Female	450	3.03	1.44	998	.047	.963
	Male	550	3.03	1.42			
Properties of Equality	Female	450	3.02	1.41	998	-.454	.650
	Male	550	2.98	1.45			
Application of Equality	Female	450	2.90	1.37	998	1.115	.265
	Male	550	3.00	1.43			

* The value is significant at Alpha level = 0.05.

Table 3 presents findings of an independent-samples t-test that was performed to investigate differences in gender conceptions about equality among students on the areas of definition, properties, and application of concepts of equality. Equality definition Female students (Mean = 3.03, SD = 1.44) and male students (Mean = 3.03, SD = 1.42) did not differ significantly, $t(998) = 0.047$, $p = 0.963$. In the same way, no gender difference was significant in regard to the properties of equality, where females scored a little higher (Mean = 3.02, SD = 1.41) than males (Mean = 2.98, SD = 1.45), $t(998) = -0.454$, $p = 0.650$. In equality application, the students who were male (Mean = 3.00, SD = 1.43) scored slightly higher than the female students (Mean = 2.90, SD = 1.37), although it was not significant $t(998) = 1.115$, $p = 0.265$. On the whole, this data points out that male and female students do not differ significantly on the conceptions of equality, which implies that both groups of students show the same level of knowledge in their definitions, properties, and application.

Conclusions

The conceptions that students have regarding equality suggest that they have a moderate idea about it. Students demonstrated a fairly superior understanding of the meaning of equality and a slight

decrease in their capability to use the concepts of equality in solving problems. They, however, had a relatively lesser comprehension of the characteristics of equality the properties of reflexivity, symmetry, and transitivity. This is an indication that, students can be aware of the concept of equality and can make efforts to apply it, but they are unable to apply the basic principles under which it is applied, thus causing misunderstandings in the process of arriving at solutions to mathematical problems that involve deeper learning in concepts. Whenever the data were analyzed in terms of gender, males and female students reported almost the same level of knowledge in all areas of equality. There were also minor differences, as the female students did a little better in the awareness of the properties of equality, whereas male students demonstrated a little bit higher skill in the application of the equality concepts. Irrespective of these minor differences, statistical tests show that the differences according to gender are not significant. This result indicates that gender is not a significant determinant of equality and conceptualization in students with respect to equality and the teaching methodology should be based on the ultimate conceptual understanding; hence, not discriminating between the genders. In general, the results emphasize that although the level of students understanding of equality is average, the aspect of properties is the most complicated one and needs specific focus during the teaching process. These conceptual gaps need to be addressed in order to improve mathematical reasoning and problem solving of the students. Teachers might have to use special teaching strategies, including concrete models, drawings, and practice, to solidify the knowledge about equality properties and make sure that students can always use these concepts in various mathematical situations. Enhancement of this preliminary knowledge is bound to enhance the confidence and mastery of mathematics in students in general.

Discussion

The results of this research imply that students have the middle level of the comprehension of the concept of equality, and their performance concerning the definition of equality is stronger than the level of their comprehension of the properties of equality. This trend is consistent with the studies that indicate that students tend to learn simple mathematical ideas better than more profound structural or relational principles underlying the simple ones (Rittle-Johnson and Schneider, 2015). Specifically, the lower performance of the students regarding the properties of equality is indicative of the enduring difficulties in internalizing abstract concepts including reflexivity, symmetry, and transitivity on which algebraic reasoning is built (Rakes and Ronau, 2019). The fact that there is not much difference in terms of gender in all of these areas indicates that these conceptual problems are not particularly group-specific, but are influenced by instructional and opportunity conditions; the same results have been found in other investigations indicating that there are very small differences in gender when comparing instruction and opportunity levels in conceptual mathematical learning (Fryer and Levitt, 2010). This brings out the fact that the problem is more of pedagogical strategies rather than the capabilities of the learners. Collectively, the findings indicate the necessity of the specific instructional practices that would focus on conceptual knowledge and meaningful practice of equality, including the use of visual representations, guided exploration, and multiple contexts to practice, which have been demonstrated to enable deeper mathematical learning (Boaler, 2015). The conceptual base of the students is key in improving the reasoning and problem-solving abilities of students in mathematics at large.

Recommendations

According to the results of the current research, the recommendation is to ensure that educators address the conceptual knowledge of equality, especially, its properties by using visual representations, manipulatives, and real-life scenarios to make abstract concepts more

straightforward. Teachers are supposed to be given professional development programs to equip training to effective instructional methods such as student centered instructional methods, inquiry based instructional methods to combat misconceptions and promote differentiated learning. The practices of assessment must consider the conceptual and procedural knowledge, but focus on reasoning and application and not just accurate responses, so as to recognize the gaps in learning and inform interventions accordingly. Also, prospective studies ought to investigate the instruction methods, including collaborative learning, technology-based methodologies, and their effect on students in the long-run to understand their mathematical knowledge so that future teaching practices can be informed through evidence-based teaching methods.

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