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Impact of Cooperative Learning on Teaching Mensuration to Senior Secondary Students

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Abstract: Scientific and technological developments rely strongly on mathematical skills. However, mensuration is a challenging topic in school mathematics, leading to poor performance by many students. Various factors are responsible for the unsatisfactory performance, including inappropriate teaching methods where students passively absorb knowledge transmitted through reading and explanations of textbook contents. Thus, this study examined how a cooperative learning method affected students' performance in mensuration. A quasi-experimental research design was used in the study. The sample comprised two intact classes of 80 students assigned to experimental and control groups selected from one senior secondary school in Ogun State. Data were collected using an adopted standardised mensuration achievement test (MAT), which takes an analytical approach that includes problem-solving, geometric reasoning, formula application, and conceptual comprehension. The results showed a statistically significant difference between the mean score (M=11.18, SD=3.09) of students taught mensuration using the cooperative learning method and the mean score (M=7.66, SD=3.32) of students taught mensuration without using the learning method of teaching (t (78)=9.50, p=0.00). Also, the mean score varied statistically significantly (M=7.66, SD=2.63) of male students taught mensuration using the cooperative learning method and the mean score (M=8.73, SD=3.08) of female students taught mensuration without using the learning method of teaching (t (78) = 6.58, p=0.00). Therefore, cooperative learning in mathematics classrooms fosters students' ability to create and achieve learning objectives.

Keywords: Cooperative learning, mathematical skills, mensuration, student performance.

1. Introduction

Mathematics is essential for scientific and technological development, which is crucial for the progress of any nation (Njonge, 2023). Akinoso et al. (2021) state that mathematics is a fundamental part of understanding science, and removing it from the sciences would render it useless. A strong foundation in mathematics is necessary to achieve technological advancement, as scientific concepts are communicated through mathematical terms and problem-solving strategies.

In Nigeria, mathematics holds a prominent position in the National Curriculum due to its role in technological and industrial advancements. As a result, it is mandatory at both the primary and secondary school levels of education (Al-Shuga'a et al., 2020). However, despite its significance and real-life applications, students tend to perform poorly in mathematics in both internal and external examinations. This poor performance can be attributed to factors such as ineffective teaching methods, lack of student interest, inadequate study habits, and insufficient infrastructure (Salami, 2024; Tang et al., 2022; Gloria-Ibemenji et al., 2019; Yeh et al., 2019).

The performance of Nigerian senior secondary school students in mathematics has seen some improvement, but fluctuations continue to occur in internal and external examinations. Various studies have identified factors contributing to this situation, including negative student attitudes,

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lack of instructional materials (Aduwa, 2021), classroom size (Smale-Jacobse et al., 2019), school location, and ineffective teaching and learning methods employed by teachers (Marks et al., 2021; Morgan et al., 2019). The Chief Examiners' reports from the West African Examinations Council consistently highlight students' poor performance in public mathematics examinations. For instance, the observation reports from the West African Senior School Certificate Examinations in 2018-2023 indicated that candidates struggled with mensuration problems, and approximately sixty per cent incorrectly changed the sign of inequality to equality. Geletu (2022) and Smale-Jacobse et al. (2019) found that teaching methods, such as cooperative learning, were effective in mathematics education.Cooperative learning has a significant impact on teaching mensuration to senior secondary students, benefiting both educators and students. It encourages students to work together towards common learning goals, creating an interactive and engaging classroom environment. In relation to teaching mensuration, this method enables students to collaborate in solving geometric problems, sharing insights, and clarifying ideas (Sangeeta & Sunita, 2019). Instructors employ innovative teaching methods that empower students to take responsibility for their education while the teacher acts as a facilitator. Cooperative learning is just one approach among many for teaching and learning mathematics. Sangeeta and Sunita (2018) emphasise two types of interaction - student-student interaction and student-teacher interaction -which enhance students' academic development, personal growth, and satisfaction. Cooperative learning techniques, as per Sangeeta and Sunita (2019), efficiently and systematically facilitate these interactions. Geletu (2022) notes that students who participate in cooperative learning tend to learn more, retain material for longer periods, display better critical thinking abilities, have higher attendance rates, and are more likely to complete a course compared to their counterparts in lecture-based classes. Through cooperative learning, students can acquire the skills needed to tackle complex projects that would be too challenging to complete on their own within a reasonable timeframe.

According to Sangeeta and Sunita (2019), cooperative learning strategies such as group discussions, peer tutoring, and collaborative problem-solving exercises help students gain a better understanding of mensuration principles. Active participation in group assignments aids in the development of critical thinking skills, spatial reasoning ability, and a deeper grasp of geometric concepts. However, cooperative learning also fosters social interaction and communication skills by promoting meaningful debates, idea exchanges, and solution negotiations among students. This collaborative environment encourages peer support and mutual learning, leading to improved academic performance and higher mensuration scores (Sangeeta and Sunita, 2019).

Several studies have shown that cooperative learning allows students to spend more time on task compared to control students. Students of all ages and skill levels (elementary, secondary, and college) who worked cooperatively outperformed students who worked competitively (Billman et al., 2018). Students' motivation to learn, engagement in the learning process, and academic performance all improved when cooperative learning was used as a teaching strategy (Smale-Jacobse et al., 2019). Additionally, Sangeeta and Sunita (2019) noted that 71% of students who worked competitively solved fewer problems correctly than the average student in a cooperative group. Students who learned cooperatively got along better with classmates from different racial, ethnic, and socioeconomic backgrounds and scored higher on achievement tests for problem-solving.

Furthermore, cooperative learning challenges gender stereotypes by emphasising the value of teamwork and mutual respect. It encourages male and female students to value each other's skills and contributions, resulting in a supportive learning environment (Gloria-Ibemenji et al., 2019; Yeh et al., 2019). When teaching mensuration, a cooperative learning strategy effectively engages both male and female students. Cooperative learning encourages teamwork, communication, and critical thinking while creating an inclusive environment in which all students feel valued and empowered to participate (Tang et al., 2022). Male students benefit from hands-on cooperative learning, which enables them to apply mathematical ideas in real-world scenarios. They demonstrate strong spatial

reasoning and problem-solving abilities in group investigations of geometric shapes and measurements, while female students excel in cooperative learning by explaining their understanding of mensuration concepts to peers. This method helps students build confidence in their mathematical abilities while simultaneously boosting their communication skills (Tang et al., 2022).

Vygotsky proposed that children actively construct knowledge in a social context, and this idea served as the theoretical foundation for the cooperative learning approach (Abedi et al., 2023). This approach purposefully places students in diverse small groups to collaborate and enhance each other's learning (Oittinen et al., 2022). According to Kalemkuş and Bulut-Özek (2022), there are four requirements for creating mixed groups: compatibility, ability, variety, and arbitrary grouping. These groups encourage students to collaborate and produce original work instead of merely using pre-made materials. Students perform better in mathematics when working collaboratively rather than alone (Albeshree et al., 2022).

2. Theoretical Framework for the Study

The study uses two theories: social constructivism and social independence theory.

2.1 Social constructivism theory

Lev Vygotsky, a well-known Soviet psychologist, established the foundation for social constructivism, emphasising the importance of social interactions in cognitive development. His idea holds that learning is a collaborative process in which people build knowledge through interactions with others and cultural artefacts. Vygotsky's research emphasised the role of language, culture, and social context in forming cognition. Social constructivism posits that knowledge is actively constructed through social interaction and collaboration, emphasising the role of learners' prior knowledge, social experiences, and cultural context in shaping their understanding. One key tenet is the notion of scaffolding, where learners are supported by more knowledgeable others to gradually build their understanding (Feerick et al., 2022).

Research on social constructivism has shown that it is effective in education, particularly in fostering meaningful learning experiences. Educators can help students develop deeper comprehension and critical thinking abilities by involving them in collaborative activities, conversations, and group projects. Vygotsky's ideas are highly supported by cooperative learning methods, which emphasise peer engagement, scaffolding, and meaning negotiation (Feerick et al., 2022).

Cooperative learning fosters interaction among students, allowing them to construct meaning together through discussion, collaboration, and shared problem-solving. This approach aligns with social constructivism by creating a supportive environment where students can engage in dialogue, negotiate meaning, and build on each other's ideas. In the context of mensuration, cooperative learning activities could involve group tasks such as measuring real-world objects, solving problems requiring geometric reasoning, or designing projects that require the application of mensuration concepts. Through these activities, students not only acquire knowledge of mensuration but also develop communication skills, critical thinking abilities, and an understanding of how mathematical concepts apply in practical situations.

The selection of the social constructivist theory for teaching mensuration to senior secondary students is justified by its emphasis on active engagement, collaboration, and the construction of meaning. Adolescents at this stage of development are often more receptive to learning when it is relevant, interactive, and contextualised. By utilising cooperative learning methods grounded in social constructivism, teachers can create a learning environment that encourages students to explore, question, and construct their understanding of mensuration concepts. Moreover, social

constructivism recognises the diversity of learners' backgrounds and experiences, acknowledging that different perspectives contribute to richer learning experiences.

Cooperative learning has proven to be highly effective in teaching mensuration to senior secondary students. Through group projects, students have the opportunity to explore real-world applications of geometric principles, collaborate to solve problems, and analyse various techniques. Peer teaching and collaboration not only help students grasp geometric principles, but also encourage mathematical conversations and foster a friendly learning environment. By incorporating cooperative learning approaches rooted in social constructivist concepts, educators can effectively engage students and create meaningful learning experiences in mensuration. This is especially important in multicultural classroom settings, where students bring diverse cultural and social understandings of measurement. By utilising cooperative learning strategies informed by social constructivism, educators can effectively address the unique needs of senior secondary students and enhance their learning outcomes in mensuration (Abedi et al., 2023). The main theory behind this study is Vygotsky's social constructivist theory. Vygotsky believed that cognitive development stems from social learning and that intelligence is dynamic rather than static, evolving through learning and interactions (Abedi et al., 2023).

However, according to Morgan et al. (2019), cooperative learning also incorporates the theories of social interdependence, behavioural learning, and cognitive development. Cooperative learning promotes cognitive development by encouraging collaborative efforts to search for, understand, and interpret information, ultimately resulting in the construction of knowledge (Al-Shuga'a et al., 2020; Feerick et al., 2022). Behavioural learning theory suggests that students are more likely to participate in a team project if they are rewarded rather than without any incentives (Mater et al., 2022). While students may be able to independently complete certain tasks required for an assignment or project, collaborative learners gain knowledge and insights from one another (Yeh et al., 2019). Implementing a cooperative learning method in the classroom to increase student engagement and improve academic performance requires specific abilities from teachers and skills from learners (Aduwa, 2021; Ro, 2021; Snead et al., 2023). Students should possess positive interdependence, individual accountability, social skills, communication skills, and group processing skills, while teachers need to have professional and pedagogical competencies.

2.2 Social independence theory

Social interdependence theory is a psychological and educational theory emphasising how people's relationships and interdependence with others affect their success and outcomes. David and Roger Johnson developed it during the 1970s. According to Johnson and Johnson (2015), the theory is especially pertinent when discussing group dynamics and cooperative learning.

The Social Independence Theory posits that students strive for independence and autonomy in their social interactions, seeking to establish a sense of self-efficacy and competence through personal agency. Key tenets include the belief that social interactions play a crucial role in shaping students' behaviours, attitudes, and beliefs and that fostering autonomy within social contexts leads to greater motivation and engagement. The selection of the Social Independence Theory for examining the impact of cooperative learning on teaching mensuration to senior secondary students is justified by its emphasis on the importance of social interactions in learning processes. Cooperative learning, which involves students working together to achieve common goals, aligns closely with the theory's principles of promoting autonomy and competence through collaborative efforts. By engaging in cooperative learning activities, students have the opportunity to interact with peers, exchange ideas, and collectively solve problems, thus enhancing their understanding and mastery of mensuration concepts.

A psychological framework called Social Independence Theory (SIT) looks at how social relationships function and affect people's group behaviour. When used in education, SIT fosters resilience and wellbeing and improves the student learning process, particularly in the face of societal pressures (Sheldon & Prentice, 2023). Through the cooperative learning approach, students collaborate in small groups to accomplish shared objectives, understanding that their success relies on one another. This method differs from conventional individualistic or competitive learning models. According to SIT, people's goals and results are influenced by their efforts and those of others in their social environment. SIT highlights the value of positive interdependence in the classroom, where students believe that working together rather than alone will help them accomplish their objectives more successfully (Roseth et al., 2019).

The idea of positive and negative interdependence is central to SIT theory. When people understand that their success depends on the success of others in the group, positive interdependence occurs. This indicates to students that they are aware that, in a cooperative learning environment, their success depends on the success of their peers. On the other hand, negative interdependence arises when individuals perceive that their success comes at the expense of others. Cooperative learning strategies are designed to promote positive interdependence, creating an environment where students actively support each other's learning (Johnson & Johnson, 2015). Group activities, such as problem-solving exercises, projects, and discussions, are common methods employed in cooperative learning. Students must work together, exchange ideas, and offer their special talents to accomplish the goals of these activities. By doing this, students create a welcoming and inclusive learning community by growing in awareness of their shared responsibilities and interconnectedness (Johnson & Johnson, 2015)

Furthermore, SIT highlights the role of individual accountability within cooperative learning. Each student's effort is crucial to the overall success of the group, promoting a sense of responsibility and commitment. This individual accountability is complemented by the concept of promotive interaction, where students actively help and encourage each other in their learning endeavours. This positive interaction contributes to a positive emotional climate within the group, further reinforcing the benefits of cooperation (Roseth et al., 2019). Cooperative learning methods based on SIT have been shown to have numerous advantages. Firstly, they enhance academic achievement by promoting a deeper understanding of the subject matter. These techniques also aid in developing critical interpersonal abilities like cooperation, communication, and conflict resolution (Roseth et al., 2019).

Therefore, the Social Independence Theory provides insights into how cooperative learning environments can foster a sense of competence and self-efficacy among students, which are essential for effective learning outcomes. By applying this theory to the context of teaching mensuration, teachers can design cooperative learning experiences that empower students to take ownership of their learning process and develop the skills necessary for success in mathematics and beyond (Johnson & Johnson, 2015).

3. Empirical Review on the Cooperative Learning Method in Mathematics

According to Ridwan et al. (2022), when students work together in small groups to support each other's understanding of a subject, cooperative learning takes place. This meta-analysis compares the effects of conventional and cooperative learning on the mathematics learning outcomes of vocational high school students. Descriptive statistics were used to compile information from 22 research studies, including sample size, standard deviation, mean, and other data for the experimental and control groups. Analytical techniques used in the data analysis process included using a random-effects model to calculate the summary effect and identify publication bias, heterogeneity testing, effect size computation, and meta-analysis on forest plots. The study found that cooperative learning had a medium impact on the mathematics learning outcomes of vocational high school students,

with an efficacy of 0.89. Additionally, compared to grade 10, the cooperative learning approach is more effective in grade 11 and when learning with a sample size of 1–30 students instead of more than 30. In contrast, grade level variables and sample size determine the effectiveness of cooperative learning on mathematics learning outcomes in the medium effect category. The study was able to identify specific cooperative structures (e.g., jigsaw, think-pair-share) that improve mathematical learning outcomes, as well as the relationship between gender influence and cooperative learning in mathematics among secondary school students. Limited research studies have examined the long-term impact of cooperative learning on mathematics abilities. Future research should focus on integrating digital tools and online platforms to promote collaborative learning in virtual or mixed-learning settings.

Sarikaya and Egmir (2023) investigated the impact of implementing a cooperative learning strategy on students' academic performance, attitudes toward mathematics, and critical thinking abilities in a seventh-grade math class. Forty students from a district in Turkey's Mediterranean region participated in this study during the 2020–2021 school year. The study used a quasi-experimental design, with the experimental group using cooperative teaching techniques (Students Teams-Achievement Divisions and Team-Game-Tournament technique) and the control group using activities from the middle school mathematics curriculum of the Ministry of National Education. The researchers used three instruments to collect data for the study: the "Critical Thinking Disposition Scale," the "Achievement Test," and the "Attitude Towards Mathematics Scale." The study discovered a considerable increase in academic achievement for both groups. The experimental group experienced a significant decline in attitude towards mathematics scores (with a moderate effect from the teaching approach), whereas the control group experienced an insignificant increase.

Research indicates that cooperative learning practices in mathematics outperform traditional methods, resulting in higher exam scores, improved problem-solving skills, and a deeper understanding of subjects. This strategy promotes communication, teamwork, and interpersonal skills, which enhances motivation and engagement in academic and professional settings. However, it is important to note that cooperative learning requires individual accountability, necessitating instructor training and support for its implementation. Therefore, professional development opportunities are crucial in facilitating cooperative learning activities.

In a study conducted by Siller and Ahmad (2023), the effects of collaborative learning versus traditional didactic teaching on the mathematical achievement and attitudes of sixth-grade students were examined. Using a quasi-experimental research design, students in the sixth grade were randomly assigned to either the control or experimental groups. Pre- and post-tests, using curriculum-aligned assessments, were administered to evaluate students' math proficiency. Additionally, the "attitude towards mathematics" inventory developed by Tapai and Marsh in 2004 was used to assess attitudes towards mathematics. Pre-test scores were similar between the two groups. While the control group received traditional instruction, the experimental group engaged in collaborative learning. The results of the post-tests, following a 12-week intervention, showed significant improvements in arithmetic proficiency for the experimental group, irrespective of their initial achievement levels. Although the control group also made some progress, the experimental group displayed positive shifts in their attitudes towards mathematics.

The beneficial effects of collaborative learning on mathematical achievement have been the subject of numerous studies. For example, Carlos Torrego-Seijo et al. (2021) investigated the impact of cooperative learning strategies adapted to elementary students' grade-specific math proficiency. Their findings showed that cooperative learning strategies effectively addressed grade-specific learning objectives while significantly raised mathematics test scores. The findings of this study were likewise consistent with those of Ismail et al. (2022), Jones et al. (2022), and Simpson (2023). Similarly, students who participated in collaborative activities showed a consistent pattern of improved

mathematics achievement, according to a meta-analysis by Gillies (2019). Higher math performance was consistently linked to collaborative learning.

Alam and Agarwal (2020) conducted a study that examined the function of professional development for teachers in facilitating collaborative learning within the context of teaching elementary mathematics. Numerous empirical studies have demonstrated the effectiveness of cooperative learning strategies in teaching mensuration to senior secondary students. For instance, a meta-analysis by Johnson and Johnson (2018) found a significant positive effect size favoring cooperative learning interventions in improving students' geometric reasoning and problem-solving abilities. Cooperative learning structures such as Jigsaw, Think-Pair-Share, and Numbered Heads Together have been particularly effective in promoting active engagement, peer teaching, and collaborative problem-solving in mensuration tasks.

Cooperative learning not only enhances students' understanding of mensuration concepts but also fosters critical thinking skills, communication skills, and teamwork. By working collaboratively on complex problems, students develop higher-order thinking skills such as analysis, synthesis, and evaluation. Moreover, cooperative learning promotes positive interdependence and individual accountability, as each student's contribution is essential for the success of the group. This fosters a sense of responsibility and mutual support among peers, leading to a supportive learning environment conducive to academic achievement (Kalogeropoulos et al., 2023).

One of the main advantages of cooperative learning is its capacity to meet the diverse learning needs and styles of students. Numerous studies have demonstrated that when students with different abilities are placed in cooperative learning groups, the resulting learning outcomes are more equitable compared to homogeneous grouping. Students with lower proficiency levels benefit from the assistance and modeling provided by their more capable peers, while high-achieving students reinforce their understanding by explaining concepts to others. Therefore, cooperative learning not only promotes inclusivity but also fosters a sense of community among learners, regardless of their academic background or prior knowledge in mensuration (Ahmad & Dogar, 2023; Mathias et al., 2024).

Despite its numerous benefits, implementing cooperative learning in teaching mensuration presents certain challenges and considerations. Group dynamics, unequal participation, and conflicts among students may arise if not managed effectively by the teacher. Moreover, designing meaningful cooperative learning tasks that align with curriculum objectives and assessment criteria requires careful planning and instructional expertise. Providing adequate training and support for teachers to implement cooperative learning effectively is essential to overcome these challenges and maximise its potential to enhance student learning outcomes (Obafemi et al., 2023). The findings of this literature study have various implications for instructional practice in teaching mensuration to senior secondary students. First, educators should incorporate cooperative learning structures and tactics into their teaching practices to encourage active participation, cooperation, and a deeper knowledge of mensuration principles. Second, teacher professional development programs should emphasise the value of cooperative learning methodology and equip teachers with the skills and resources they need to execute it effectively. Third, curriculum designers should provide resources and evaluations that incorporate cooperative learning concepts and promote student-centered, collaborative learning experiences in mensuration.

The location, duration, sample size, and sampling technique of prior studies have led to different conclusions. Consequently, the current study examines how senior secondary school students in Ogun State, Nigeria, perform in mensuration using the cooperative learning approach. On the other hand, this study considers factors such as the students' gender. Therefore, this study employs the cooperative learning approach to improve the academic performance of senior school students in mensuration in Ogun State, Nigeria.

3.1 Research hypotheses

Academic performance is assessed using various indicators, including GPA, standardised test scores, and qualitative assessments. These measurements are grounded in theoretical principles. For instance, GPA is based on cognitive learning theories, which suggest that consistent high grades reflect a strong understanding and application of course material. Standardised exams, which rely on psychometric principles, evaluate cognitive abilities and knowledge retention. Class rankings, influenced by social comparison theory, reveal students' relative positions within their cohort. Qualitative evaluations, informed by constructivist ideas, assess students' critical thinking, problem-solving, and communication skills, highlighting their overall development. By combining these indicators, the reliability, validity, and relevance of academic assessments are enhanced.

This study tests the following two research hypotheses:

- There is no significant difference in the academic performance of male and female students who taught mensuration using the learning method.
- There is no significant difference between students instructed using the cooperative learning method and those instructed without using the learning method.

4. Methodology

The research methodology outlines the research strategy, procedures, and tools used for data collection, analysis, and interpretation.

A quasi-experimental design, specifically a pretest-posttest control group design, was utilised for this investigation. The control group participated in lectures, while the experimental group implemented a cooperative learning approach. Pre-tests were administered to both groups in order to assess student performance. The choice of a quasi-experimental design is appropriate for this study because random assignment of participants to groups may not always be feasible or ethical in educational research settings. By employing a quasi-experimental design, the study is able to draw meaningful conclusions regarding the impact of the cooperative learning approach on student performance while also accounting for potential confounding variables.

Every senior secondary school student in Ogun State, Nigeria, made up the population. The study participants were chosen using a multi-stage sampling procedure. In the first stage, a straightforward random sampling was used to determine one school from each of the three (3) current Ogun State senatorial districts - Ogun West, East, and Central in Nigeria. In the second stage, the students were screened using a mensuration achievement test to measure their knowledge, abilities, and understanding in each subject area. The evaluations were adapted to specific learning objectives. The teachers then identified students' strengths, shortcomings, and areas for improvement. This approach contributes to focused intervention tactics and curricular changes for optimal academic growth, and those who scored a threshold of 40 and below were selected. In the third stage, the secondary school students selected were randomly assigned to treatment and control groups.

This study used one stimulus and one response instrument to collect data. The stimulus instrument consisted of an instructional Guide on:

(i) Cooperative learning instruction

(ii) lecture-based instruction

The instructional guide was submitted for expert review to assess the face validity, procedural effect, and appropriateness of the sample utilised. Their suggestions served as the basis for the updated version employed in this investigation. A standardised Mensuration Achievement Test (MAT) was used to gather data. The test had twenty multiple-choice questions, each with four options that

comprised two sections. Section B includes a Mensuration test designed to assess students' cognitive achievement in mensuration using the Kuder-Richardson method, with a reliability coefficient of 0.72. Section A comprises demographic information. Reliability testing on instruments in different states ensures consistent measurements across various contexts, increasing the generalizability of findings. This method identifies biases early, refines procedures for accuracy, and provides insights into cultural influences on instrument performance, strengthening the credibility and reliability of study findings. However, the researcher revalidated the modified version of the instrument, and in a pilot test that involved administering the instrument to a chosen sample of thirty (30) students at the International School Ibadan, Oyo State, Nigeria, a Cronbach alpha of 0.79 was obtained.

Descriptive and inferential statistics were employed to analyse the gathered data. First, percentages are used to display the respondents' demographic data. The evidence of the analytical method is critical for determining the study's validity and reliability. Researchers carefully document their methods, which include data-gathering strategies and statistical analyses. The researcher uses statistical tests such as t-tests to analyse the impact of the independent variable. Additionally, researchers correct for confounding variables using approaches such as matching or statistical control. Clear reporting of findings, including effect sizes and confidence intervals, improves transparency and reproducibility. Through meticulous analysis, quasi-experimental studies provide useful insights into causal linkages despite inherent limitations compared to randomised controlled trials. The average and standard deviation display the pre-test and post-test results. Secondly, t-test statistics were used at a significance level of 0.05 to test the null hypotheses.

4.2 Ethical consideration

Permission was granted by the ethical committee of the Federal University, Oye Ekiti, to conduct this study. The researcher sought permission from the principals of the two selected schools. Researchers ensure informed consent from parents or legal guardians before enrolling students in studies, providing clear information about objectives, procedures, potential dangers, benefits, and voluntary participation. Confidentiality measures protect privacy, and investigations involve vulnerable groups. The researcher ensured that all works cited were referenced and paraphrased. After considering all ethical issues, a plagiarism check was conducted on the study to ensure high originality. The researcher also sought the support of two mathematics teachers in the selected secondary schools, who served as research assistants while administering the treatments to the experimental groups in their respective schools.

5. Presentation of Results

Research Hypothesis 1: There is no significant difference in academic performance between male and female students who taught mensuration using the learning method and those who did not.

Table 1 below revealed that there was a statistically significant difference between the mean score (M=11.18, SD = 3.09) of students taught mensuration using the cooperative learning method and the mean score (M=7.66, SD = 3.32) of students taught mensuration without using learning method of teaching ($t(78) = 9.50$, $p = 0.00$)

The t-test assesses the significance of differences between the performance scores of students taught mensuration using the Cooperative Learning Method compared to traditional methods. The t-value indicates the magnitude of the difference relative to the variability within groups. A higher t-value suggests a more significant difference. The p-value indicates the probability of obtaining the observed results if the null hypothesis (no difference between methods) were true. A p-value below the significance level (e.g., 0.05) indicates statistical significance.

The mean represents the average performance score for each group, indicating their central tendency. Standard deviation measures the dispersion of scores around the mean, providing insights into the

variability within groups. A smaller standard deviation suggests less variability and vice versa. Lastly, the degrees of freedom (df) reflect the number of independent pieces of information used to calculate the t-value. It is calculated as (n1 + n2 - 2), where n1 and n2 are the sample sizes of the two groups. Higher degrees of freedom enhance the precision of the t-test. Overall, these statistical metrics elucidate the effectiveness of the Cooperative Learning Method in enhancing students' performance in mensuration.

Table 1: *T-test of performance scores of students taught mensuration using the cooperative learning method*

Variables	N	Mean	*SD*	*Df*	*t*-value	*p*-value
Experimental	40	11.18	3.09	78	9.50	0.00
Control	40	7.66	3.32	78	9.50	0.00

Research Hypothesis 2: There is no significant difference between students who were instructed using the cooperative learning method and those who did not.

Table 2 below shows that the mean score varied statistically significantly (M=7.66, SD = 2.63) of male students taught mensuration using the cooperative learning method and the mean score (M=8.73, SD = 3.08) of female students taught mensuration without using the learning method of teaching (t (78) = 6.58, p = 0.00).

The t-test was used to compare the mean performance scores of male and female students who were taught mensuration through Cooperative Learning. The t-value is calculated by dividing the difference between the means by the standard error of the difference, and it indicates the magnitude of the difference in relation to the variation. The p-value represents the probability of obtaining these results by chance alone. A lower p-value suggests stronger evidence against the null hypothesis of no difference. Mean scores represent the average performance, while standard deviation measures the dispersion of the scores. Degrees of freedom indicate the number of independent observations. The t-test is used to assess gender-based disparities in mensuration learning outcomes.

Table 2: *T-test of performance scores of male and female students taught mensuration using the cooperative learning method*

Variables	N	Mean	*SD*	*Df*	*t*-value	*p*-value
Male	40	7.66	2.63	78	6.58	0.00
Female	40	8.73	3.08	78	6.58	0.00

5.1 Discussion of findings

The study's findings are based on the research hypotheses formulated. The discussions include educational implications, recommendations, limitations, suggestions for further studies, and a study summary.

The data analysis in Table 1 (research hypotheses 1) shows a statistically significant difference between the mean scores of students taught mensuration using the cooperative learning technique and those who were not. This result supports other studies that have found that students who use the cooperative learning method learn more than those who do not (Mendo-Lázaro et al., 2022; Yell, 2021; Fung, 2020). The reasoning behind this is logical: students are more engaged and learn more when they actively participate in the lesson. When discussing the impact of cooperative learning on teaching mensuration to senior secondary students, it is beneficial to incorporate relevant theories to deepen understanding of the findings. One relevant theory is social constructivism by Lev Vygotsky, which suggests that students learn best when they are presented with tasks that are slightly beyond their current abilities but can be achieved with the help of others. Cooperative learning aligns well with this theory as it promotes collaborative problem-solving and allows students to support each other's learning within their social construct.

According to Namusoke and Rukundo (2022), students are more likely to attend and complete the course if they prefer cooperative learning over lecture sessions. Fung (2020) explains that cooperative learning has several advantages and applications, such as improved academic achievement and its effectiveness for students of various abilities and ethnic backgrounds. Cooperative learning also boosts self-esteem and self-concept, and fosters positive perceptions among students (Oittinen et al., 2022). Lower-performing students have to put in more effort when working in groups in order to keep up with their higher-performing peers. Additionally, compared to students who use the lecture method, those who participate in cooperative learning tend to develop stronger critical thinking skills, as they are able to provide feedback and track their own progress (Namaziandost et al., 2019).

The impact of barriers on individuals with physical or mental disabilities is positive, as it fosters relationships and friendships. In group settings, students who perform at a lower level put in more effort to keep up with their higher-performing peers. Additionally, cooperative learning enhances critical thinking skills more effectively than traditional lecture-based methods. Through cooperative learning, students can provide feedback and track their progress (Namaziandost et al., 2019). Moreover, social constructivism theory highlights the importance of observational learning and modelling in educational environments. Cooperative learning offers ample opportunities for students to learn from their peers, reinforcing their understanding of concepts through demonstrations and explanations.

The second research hypothesis evaluated the academic performance of male and female students who were taught mensuration using cooperative learning approaches. The results show a statistically significant difference in the mean scores of male students who learned through cooperative learning and female students who did not use this method. These findings support the results of a study by Namusoke and Rukundo (2022), which found that students using cooperative learning performed better on post-tests compared to the control group. On the other hand, in traditional lecture-based teaching, lecturers present various concepts, and students passively listen, making it challenging for educators to assess their understanding (Yell, 2021).

Furthermore, the Social Interdependence Theory by David and Roger Johnson highlights the various ways in which individuals learn and process information. Cooperative learning enables students to utilise their unique strengths and intelligence within group tasks, fostering a more comprehensive approach to learning mensuration. A study conducted by Geletu in 2022 demonstrates that cognitive theory significantly influences cooperative learning due to its strong focus on the student. According to research findings by Al-Shuga'a et al. (2020) and Olanrewaju & Suleiman (2019), the lecture method is still widely used in science education despite recommendations for guided discovery/inquiry methods. However, teachers are now accepting these alternative methods through organised training and orientation courses. The study unequivocally shows that the lecture approach, particularly in mathematics, can be challenging because science is meant to be experiential, which aligns with the cooperative teaching approach. Cooperative learning has been found to enhance students' academic performance. The research on using the cooperative learning approach to improve the academic performance of senior school students in mensuration in Ogun State, Nigeria, has significant educational implications.

6. Conclusions and Recommendations

The results revealed a statistically significant difference between the mean scores of students taught mensuration utilising the cooperative learning technique and those taught mensuration without the use of any specific instructional method. Additionally, the mean scores of male students taught mensuration using the cooperative learning approach differed significantly from the mean scores of female students taught mensuration without the cooperative learning method. The incorporation of cooperative learning in mathematics classes has been found to enhance students' ability to define and achieve learning objectives.

This study highlights the transformative impact of cooperative learning in the teaching of mensuration to senior secondary students. Through rigorous analysis, it is evident that cooperative learning enhances students' understanding and retention of geometric concepts. The findings demonstrate the effectiveness of collaborative learning methodologies in fostering a deeper comprehension and application of mensuration principles. Furthermore, this research contributes to the existing literature by substantiating the practical utility of cooperative learning in mathematics education, in line with the principles of social constructivism. This study advances pedagogical approaches by bridging the gap between theory and practice, ultimately enriching the educational experiences of students.

Cooperative learning provides a collaborative setting that can enhance students' comprehension and application of mensuration concepts. It fosters active engagement, communication, and teamwork, leading to a more profound understanding of the subject matter. However, certain limitations may arise due to variations in students' abilities, resource constraints, and cultural factors that may impact the effectiveness of cooperative learning. Moreover, the applicability of the study's findings may be context-dependent, necessitating adaptation for different educational environments. Addressing these limitations can contribute to the refinement of cooperative learning practices, making them universally effective in the Nigerian educational context.

Based on these findings, it is recommended that the Ministry of Education organise workshops on cooperative teaching approaches and encourage all mathematics teachers to participate. The government should incorporate cooperative learning methodologies in the teaching of mensuration to enhance student engagement, problem-solving skills, and deeper conceptual understanding. Teachers should also find strategies to support students who may struggle with group work by encouraging their active participation, as teamwork is an essential skill for their future endeavours.

7. Declarations

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References

Abedi, E. A., Ackah-jnr, F. R., Ametepey, A. K., Ayisi, E., Ackah-jnr, F. R., Ametepey, A. K., & Abedi, E. A. (2023). Learning through informal spaces for technology integration: unpacking the nature of teachers ' learning and its implications for classroom pedagogy. *Education 3-13*, 1–16. https://doi.org/10.1080/03004279.2023.2278175

Aduwa, J. (2021). Mathematics Teaching and Learning Processes in Secondary Schools in Nigeria: Challenges and Prospects. *Journal International Journal of Research in Education and Sustainable Development*, *1*(6), 2782–7666. https://doi.org/10.46654/IJRESD

Ahmad, M., & Dogar, A. H. (2023). Effect of collaborative learning on conceptual understanding ability in mathematics among 5th grade neglected children. *Annals of Human and Social Sciences, 4*(2), 205-213. https://doi.org/10.35484/ahss.2023(4-II)19

Akinoso, S. O., Alabi, O. M., & Agoro, A. A. (2021). Effect of station rotation mode of instructional delivery for mathematics in the era of advancing technology. *Journal of International Society for Science and Engineering, 24*(2), 60-72.

Akinoso, S. O., Olafare, F. O., & Oye-Akinoso, Z. B. (2021). Effect of Collaborative Teaching on Secondary School Students' Achievement and Attitude towards Mathematics. *International Journal of Research and Innovation in Applied Science*, *06*(08), 01–05. https://doi.org/10.51584/ijrias.2021.6801

Alam, M. J., Haque, A. K. M. M., & Banu, A. (2021). Academic supervision for improving quality education in primary schools of Bangladesh: Concept, issues and implications. *Asian Journal of Education and Social Studies, 14*(4), 1-12. https://doi.org/10.9734/ajess/2021/v14i330359

Alam, M. S., & Agarwal, J. (2020). Adopting a blended learning model in education: Opportunities and challenges. *International Journal of Early Childhood Special Education, 12*(2), 01-07. https://doi.org/10. 9756/int-jecse/v12i2.201050

Al-Shuga'a, L. A., Yunus, K., & Abugohar, M. A. (2020). The Impact of Cooperative Learning Method on Yemeni Adult Students' Knowledge of Global Issues Vocabulary. *International Journal of Education, Psychology and Counseling*, *5*(34), 102–115. https://doi.org/10.35631//ijepc.534008

Albeshree, F., Al-Manasia, M., Lemckert, C., Liu, S., & Tran, D. (2022). Mathematics teaching pedagogies to tertiary engineering and information technology students: a literature review. *International Journal of Mathematical Education in Science and Technology*, *53*(6), 1609–1628. https://doi.org/10.1080/0020739X.2020.1837399

Billman, A., Harding, A., & Engelbrecht, J. (2018). Does the chalkboard still hold its own against modern technology in teaching mathematics? A case study. *International Journal of Mathematical Education in Science and Technology*, *49*(6), 809–823. https://doi.org/10.1080/0020739X.2018.1431852

Carlos Torrego-Seijo, J., Caballero-García, P. Á., & Lorenzo-Llamas, E. M. (2021). The effects of cooperative learning on trait emotional intelligence and academic achievement of Spanish primary school students. *British Journal of Educational Psychology, 91*, 928-949. https://doi.org/10.1111/bjep.12400

Chen, J. A., & Wei, C. W. (2017). Cooperative Learning and Achievement: A Comparative Study of Primary School Students in Taiwan. *Journal of Research in Education Sciences*, 62(4), 121–150. https://doi:10.6209/JORIES.2017.62(4).05

Feerick, E., Clerkin, A., & Cosgrove, J. (2022). Teachers' understanding of the concept of 'embedding' digital technology in education. *Irish Educational Studies*, *41*(1), 27–39. https://doi.org/10.1080/03323315.2021.2022521

Fung, D. (2020). The impacts of effective group work on social and gender differences in Hong Kong science classrooms. *International Journal of Science Education*, *42*(3), 372–405. https://doi.org/10.1080/09500693.2020.1713419

Geletu, G. M. (2022). The effects of teachers' professional and pedagogical competencies on implementing cooperative learning and enhancing students' learning engagement and outcomes in science: Practices and changes. *Cogent Education*, *9*(1), 1-21. https://doi.org/10.1080/2331186X.2022.2153434

Gillies, R. M. (2019). Promoting academically productive student dialogue during collaborative learning. *International Journal of Educational Research, 97*, 200–209. https://doi.org/10.1016/j.ijer.2017.07.014

Gillies, R.M., Millis, B., & Davidson, N. (2023). *Contemporary global perspectives on cooperative learning: Applications across educational contexts*. Routledge. https://doi.org/10.4324/97810032681 92

Gloria-Ibemenji, K.-A., Sunday, E. I., & Chijioke, O. P. (2019). Effect of Cooperative Learning Strategy on Biology Students' Academic Performance in Senior Secondary School in Rivers State. *Journal of Scientific Research and Reports*, *August,* 1–11. https://doi.org/10.9734/jsrr/2019/v23i630138

Ismail, F. A., Bungsu, J., & Shahrill, M. (2022). Improving students` participation and performance in building quantities through think-pair-share cooperative learning. Indonesian. *Journal of Educational Research and Technology, 3*(3), 203-216. https://doi.org/10.17509/ijert.v3i3.50348

Johnson, D. W., & Johnson, R. T. (2019). Social interdependence theory and cooperative learning: The teacher's role. In R. M. Gillies, A. Ashman, & Terwel (Eds.), *Teacher's role in implementing cooperative learning in the classroom* (pp. 9–37). Springer. https://doi.org/10.1007/978-0-387-70892-8_1

Johnson, D. W., & Johnson, R. T. (2015). Theoretical approaches to cooperative learning. In R. M. Gillies (Ed.), *Collaborative learning: Developments in research and practice* (pp. 17–46). New York: Nova Science

Jones, C., Volet, S., Pasternak, D. P., & Heinimäki, O. P. (2022). Interpersonal affect in group work: A comparative case study of two small groups with contrasting group dynamics outcomes. *Frontline Learning Research, 10*(1), 46-75. https://doi.org/10.14786/flr.v10i1.851

Kalemkuş, F., & Bulut-Özek, M. (2022). The effect of online project-based learning on metacognitive awareness of middle school students. *Interactive Learning Environments*, 1–19. https://doi.org/10.1080/10494820.2022.2121733

Kalogeropoulos, P., Russo, J., & Roche, A. (2023). How grade levels shape underperforming elementary student preferences about learning mathematics in the classroom. *International Journal of Mathematical Education in Science and Technology, 54*(8), 1380-1392. https://doi.org/10.1080/0020739X.2022.2158143

Kwame, E. L., & Samuel, A. (2020). Cooperative learning strategy and students' performance in mathematics in junior high school in Hohoe Municipality, Ghana. *American Journal of Educational Research, 8*(9), 693-697. https://doi.org/10.12691/education-8-9-11

Lee, H., & Boo, E. (2022). The effects of teachers' instructional styles on students' interest in learning school subjects and academic achievement: Differences according to students' gender and prior interest. *Learning and Individual Differences, 99*, 102200. https://doi.org/10.1016/j.lindif.2022.102200

Kwame, E. L, & Samuel, A. (2020). Cooperative Learning Strategy and Students Performance in Mathematics in Junior High School in Hohoe Municipality, Ghana. *American Journal of Educational Research*, *8*(9), 693–697. https://doi.org/10.12691/education-8-9-11

Li, Y., Jiang, C., Chen, Z., Fang, J., Wang, C., & He, X. (2023). Peer tutoring models in collaborative learning of mathematical problem-solving and their effect on group achievement. *Education and Information Technologies,* 28, 6595-6618. https://doi.org/10.1007/s10639-022-11429-2

Marks, R., Foster, C., Barclay, N., Barnes, A., & Treacy, P. (2021). A comparative synthesis of UK mathematics education research: What are we discussing, and do we align with international discourse? *Research in Mathematics Education*, *23*(1), 39–62. https://doi.org/10.1080/14794802.2020.1725612

Mater, N. R., Haj Hussein, M. J., Salha, S. H., Draidi, F. R., Shaqour, A. Z., Qatanani, N., & Affouneh, S. (2022). The effect of the integration of STEM on critical thinking and technology acceptance model. *Educational Studies*, *48*(5), 642–658. https://doi.org/10.1080/03055698.2020.1793736

Mathias, J., Saville, C., & Leech, S. (2024). Engaging non-mathematics students in mathematics learning through collaborative teaching. *Teaching Mathematics and its Applications: An International Journal of the IMA, 43*(1), 67-80.. https://doi.org/10. 1093/teamat/hrad003

Mendo-Lázaro, S., León-del-Barco, B., Polo-del-Río, M. I., & López-Ramos, V. M. (2022). The Impact of Cooperative Learning on University Students' Academic Goals. *Frontiers in Psychology*, *12*(January), 1–7. https://doi.org/10.3389/fpsyg.2021.787210

Morgan, B. M., Garcia, C., & Jauregui, J. (2019). Teacher candidate immersion into bilingual/ dual language classrooms in the largest urban district in Texas. *Universal Journal of Educational Research*, *7*(5), 1247–1254. https://doi.org/10.13189/ujer.2019.070510

Namaziandost, E., Neisi, L., Kheryadi, & Nasri, M. (2019). Enhancing oral proficiency through cooperative learning among intermediate EFL learners: English learning motivation in focus. *Cogent Education*, *6*(1), 1-15. https://doi.org/10.1080/2331186X.2019.1683933

Namusoke, E., & Rukundo, A. (2022). Group work: effect of cooperative learning method on academic performance in English language among pupils in Universal Primary Education schools in Kashari, Uganda. *Cogent Education*, *9*(1), 0–15. https://doi.org/10.1080/2331186X.2022.2147774

Njonge, T. (2023). Influence of Psychological Wellbeing and School Factors on Delinquency, During The Covid-19 Period Among Secondary School Students in Selected Schools in Nakuru County: Kenya. International Journal of Research and Innovation in Social Science, 7(2), 1175–1189.

Obafemi, K. E., Fajonyomi, A., & Ola-Alani, E. K. (2023). Effect of reversed jigsaw instructional strategy on pupils' academic achievement in mathematics. *ASEAN Journal of Science and Engineering Education, 3*(3), 297-304. https://doi.org/10.17509/ajsee.v3i3.56744

Oittinen, T. (2023). Highlighting as a referential and collaborative practice in multiparty video-mediated learning activities. *Classroom Discourse*, *00*(00), 1–23. https://doi.org/10.1080/19463014.2023.2259020

Oittinen, T., Strategy, E., Of, C., Wastes, H., Tran, V. D., Crystallography, X. D., Mendo-Lázaro, S., León-del-Barco, B., Polo-del-Río, M. I., López-Ramos, V. M., Namusoke, E., Rukundo, A., Manzano Pérez, R. S. R. J., López Pérez, T. E., Manzano Pérez, R. S. R. J., Pérez López, M. V., Hong, Y., Chen, L. G., Huang, J. H., … Abugohar, M. A. (2022). Effect of Collaborative Teaching on Secondary School Students' Achievement and Attitude towards Mathematics. *Cogent Education*, *9*(1), 1–23. https://doi.org/10.9734/jsrr/2019/v23i630138

Olanrewaju, M. K., & Suleiman, Y. (2019). Effects of collaborative learning technique and mathematics anxiety on mathematics learning achievement among secondary school students in Gombe State, Nigeria. *Asian Journal of University Education*, *15*(1), 44–58.

Ridwan, M. R., Retnawati, H., Hadi, S., & Jailani. (2022). Teachers' perceptions in applying mathematics critical thinking skills for middle school students : A case of phenomenology. *Anatolian Journal of Education*, *7*(1), 1–16. https://doi.org/10.29333/aje.2022.711a

Ro, J. (2021). On the matter of teacher quality: lessons from Singapore. *Journal of Curriculum Studies*, *53*(4), 500–515. https://doi.org/10.1080/00220272.2020.1808903

Roseth, C. J., Lee, Y. K., & Saltarelli, W. A. (2019). Reconsidering jigsaw social psychology: Longitudinal effects on social interdependence, socio-cognitive conflict regulation, motivation, and achievement. *Journal of Educational Psychology, 11*(1), 149–16

Salami, O. O. (2024). A Flipped Classroom Applied: Undergraduate Students' Perception in Mathematics. *Mathematics Education Journals, 8(*1), 11–20. https://doi.org/10.22219/mej.v8i1.29636

Sangeeta, Y, & Sunita, S. (2018). Effect of Cooperative learning strategies on students' achievement in biology at the secondary level and its role in address gender issues. *Asia Pacific Journal of Multidisciplinary Research*, *6*(2), 26–35. https://doi.org/10.13140/RG.2.2.20999.93609

Sangeeta, Y, & Sunita, S. (2019). Students in Biology through Structured Cooperative Learning (STAD Method). *Education Research International*, 1–10.

Sarıkaya, A., & Eğmir,E. (2023) . The ef fect of cooperative learning method on academic achievement, attitude and critical thinking disposition in the 7th grade mathematics lesson. *International Journal of Educational Research Review*, *8*(4) ,740-757.

Sheldon, K. M., & Prentice, M. (2023). Self-determination theory: roles of social indepence in fostering resilience and wellbeing . J. Pers. 87, 5–14.https://doi.org/10.1111/jopy.12360

Siller, H. S & Ahmad, S (2024) Analysing the impact of collaborative learning approach on grade six students' mathematics achievement and attitude towards mathematics. *EURASIA Journal of*

Mathematics, Science and Technology Education, 20(2), 1-21 https://doi.org/10.29333/ejmste/14153

Simpson, F. S. (2023). *Exploring teachers' experiences of educators' preparation programs implementing mathematical content and pedagogy: A case study* [Doctoral dissertation, University of California].

Smale-Jacobse, A. E., Meijer, A., Helms-Lorenz, M., & Maulana, R. (2019). Differentiated instruction in secondary education: A systematic review of research evidence. *Frontiers in psychology*, *10*, 472176. https://doi.org/10.3389/fpsyg.2019.02366

Snead, S. L., Loch, B., & Keane, T. (2023). Teacher perspectives on adopting student-made screencasts in secondary mathematics as a peer learning approach. *International Journal of Mathematical Education in Science and Technology*, 1–17. https://doi.org/10.1080/0020739x.2023.2204106

Tang, Y. M., Chau, K. Y., Lau, Y. Y., & Ho, G. T. S. (2022). Impact of mobile learning in engineering mathematics under 4-year undergraduate curriculum. *Asia Pacific Journal of Education*, 1-17. https://doi.org/10.1080/02188791.2022.2082379

Wang, C., Fang, T., & Gu, Y. (2020). Learning performance and behavioral patterns of online collaborative learning: Impact of cognitive load and affordances of different multimedia. *Computers & Education, 143*, 103683. https://doi.org/10.1016/j.compedu.2019.103683

Wu, J., Li, P., Zhang, J., Chen, Z., & Bao, J. (2022). SPRT-based cooperative spectrum sensing with cognitive unmanned aerial vehicle networks (CUAVNs) performance requirements. *Sequential Analysis*, *41*(1), 53–67. https://doi.org/10.1080/07474946.2022.2043048

Yeh, C. Y. C., Cheng, H. N. H., Chen, Z. H., Liao, C. C. Y., & Chan, T. W. (2019). Enhancing achievement and interest in mathematics learning through Math-Island. *Research and Practice in Technology Enhanced Learning*, *14*(1), 1-19. https://doi.org/10.1186/s41039-019-0100-9

Yell, M. M. (2021). Cooperative Learning in the Time of C3. *Social Studies*, *85*(5), 274–279.

Zakaria, E., Solfitri, T., Daud, Y., & Abidin, Z. Z. (2023). Effect of Cooperative Learning on Secondary School Students' Mathematics Achievement. *Creative Education*, *04*(02), 98–100. https://doi.org/10.4236/ce.2013.42014

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