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Effect of Representation Strategies on Secondary School Students' Mathematics Achievement: A Case Unguja Island, Zanzibar

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Abstract: This study sought to establish the effect of representations strategies on Secondary School students' Mathematics Achievement in Unguja Island, Zanzibar. Four out of sixteen public secondary schools located in the urban district of Unguja Island were randomly selected. Two of these schools were assigned as the experimental group while the other two were the control group. Participants were students from level three who were sampled based on the type of group to which the school is assigned. Achievement tests (pre-test and post-test) based on mathematics topics of relation and function were used as an instrument for data collection. Data was analyzed quantitatively in terms of descriptive statistics and t-tests. The study established no initial difference in performance between the control and the experimental groups. After the intervention, the experimental group which used multiple representation strategies outperformed the control group. Therefore, the study recommends that teachers should implement multiple representation strategies during the mathematics teaching. Additionally, teachers should be provided with in-service training on proper utilization of varieties of representation strategies in teaching and learning of mathematics for better results to be realized.

Keywords: Mathematics achievement test; representations; teaching; learning; mathematics; multiple representations; strategies.

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Introduction

Determination of the competence of the young generation in the education system is mostly observed in science and mathematics subjects. Specifically, mathematics subject has been given a heavy load in the school curriculum compared to other subjects, considering it to be the most fundamental of all science subjects (Sa'ad, Adamu &

Sadiq, 2014), the basic entry requirement for different courses at universities, vocational colleges and other professional studies, the basic tool for scientific, technology and socio-economic development (Mbugua, Kibet, Muthaa, & Nkonke, 2012; Sa'ad et al., 2014) and the great contribution in the field of Science, Technology, Engineering, and mathematic (STEM) education. Learners of the 21st century are supposed to acquire knowledge, skills and attitude that enable them to fit with the current world and be able to interpret the current situation in its real sense. Hence, skills such as critical thinking, problem-solving, creativity, innovation, communication, collaboration, visual literacy, and scientific and numerical literacy are appropriate and are needed to be acquired by mathematics learners (Häkkinen, Järvelä, Mäkitalo & Ahonen, 2016; Yıldırım & Topalcengiz, 2019). Successful achievements of these competencies are attained through active learning of mathematics. Hence, teachers are supposed to understand their role in students' learning of these skills.

Numerous studies stressed a better way of representing mathematics concepts and a good choice of instructional strategies, which signifies the quality of mathematics learning. According to Javed, Saif and Kundi (2013), a poor method of mathematics teaching in Pakistan is among the major reasons for the low literacy rate. An effective mathematics teacher can create an active classroom environment through the choice of appropriate teaching strategies that will actively involve students to learn mathematics more effectively (Dirlikli & Akgun, 2017). Hence, the correct choice of an instructional strategy does not only depend on the teachers' knowledge of the subject matter but also on the teacher's knowledge of the learners' level of understanding (Shulman, 1987).

A review of literature revealed that mathematical knowledge of strategies in multiple representations is the fundamental aspect of effective mathematics learning. According to Shulman, (1987), the action of teaching is said to be taking place if the learner acquires new knowledge through the teacher's classroom activities in which learners are provided with multiple representations of the concepts and multiple strategies to ensure the attainment of all objectives. Therefore, mathematics teachers can use this opportunity to effectively implement multiple representation strategies so that the transfer of mathematics knowledge and skills become successful for the learners.

The Ministry of education and vocational training in Zanzibar currently implements the reviewed curriculum of ordinary secondary schools in Tanzania (Ministry of Education and Vocational Training, 2007). This curriculum was designed to reform classroom teaching strategies (Ministry of Education and Vocational Training, 2010) and it provides an opportunity for learners to acquire basic knowledge, skills, and attitude. Thus, the whole process of teaching and learning depends on the unique competence of the teacher in using various strategies.

However, secondary school mathematics teachers still face challenges in implementing this new curriculum. Among the challenges is the lack of teachers' attention in utilizing multiple strategies in classroom practices. In their study conducted in Zanzibar, Moh'd, Uwamahoro, Nzotungicimpaye, and Orodho (2021) revealed that most mathematics teachers were found to limit themselves to use a single strategy with little engagement of students in learning activities.These teachers restricted themselves from presenting mathematics concepts and providing real-life examples in multiple ways. Hence the level of mathematics strategies in representing the concepts limited the required standards.

A study conducted in secondary schools in Tanzania found that inspiration, commitment and support provided by subject teachers, the availability of teachers and their teaching approaches, and the relevance of the subject to their daily life experiences are the main basis for students to a prefer a particular subject (Ndalichako & Komba, 2014). Lacking these to mathematics teachers resulted in low enrolment of students in mathematics subjects as well as low performance in the subject. For this reason, this study sought to establish the effect of representations strategies on Secondary School students' Mathematics Achievement in Unguja Island, Zanzibar. The study was guided by the following two research questions:

1. Is there a significant difference in the score of the experimental and the control groups before and after the intervention?
2. Is there a significant difference in the mathematics achievement scores of the experimental group before and after the treatment?

Strategies for Mathematics Representations

Several scholars regard knowledge of mathematics representations as among the strategic components of Pedagogical Content Knowledge (PCK) required by mathematics teachers to make meaningful learning. Shulman (1986: p.9) defined PCK as "the most useful forms of representation of those ideas, the most powerful analogies, illustrations, examples, explanations and demonstrations. Thus, it is ways of representing and formulating the subject that make it comprehensible to others…" Mishra and Koehler (2006:p.1027) observed PCK as "that knowledge base which is concerned with the representation and formulation of concepts, pedagogical techniques and knowledge of what makes concepts difficult or easy to learn, and knowledge of learners' prior knowledge". According to Rohaan, Taconis and Jochems (2009), PCK is observed as that knowledge involves teaching strategies that incorporate appropriate conceptual representations in order to address learner difficulties and misconceptions and to foster meaningful understanding. In this view, the multiple representations strategy becomes undeniable to be implemented by mathematics teachers for better classroom practices in teaching mathematics.

Knowledge of strategies related to mathematics representations involves different forms. It incorporates the use of appropriate activities in instruction, the use of various real-life examples and analogies in instruction, the use of different instructional strategies in presentation, and the making use of multiple representations in instruction (Sibuyi, 2012). According to Moh'd, Uwamahoro, Nzotungicimpaye & Orodho (2021), this type of knowledge encourages the use of learner-centered approaches in order to involve students in the learning process, utilize various instructional strategies suitable to teach a particular topic, make use of teaching approaches that stimulate students' creativity and authorize them to solve the problem, together with the use of a range of representations, diversities as well as appropriate and real-life examples to clarify concepts. This is to say, teachers become enriched with the techniques required to impart meaningful learning.

Literature has recognized mathematical representation strategies as an efficient way of teaching concepts. Among the consideration for effective mathematics teaching with competent, PCK as revealed by Ijeh and Nkopod (2013) is the efficient way of developing a concept together with suitable knowledge of teaching strategies that will fit students and their needs in learning. On the other hand, representation has been recognized to act as a means for manipulation, communication, and the conceptualization of the understanding of mathematical ideas (Zazkis & Liljedahl, 2004). Therefore, it overcomes the challenges that appear during the process of teaching and learning mathematics.

Mathematics representation strategies provide an opportunity for students to enjoy lessons, hence motivating their learning process. Excellent teachers of mathematics are aware of a wide range of effective teaching strategies and techniques for teaching and learning mathematics that promote the learners' enjoyment of the subject (Ingvarson, Beavis, Bishop, Peck, & Elsworth, 2004). Furthermore, such teachers usually choose to teach strategies that tend to create the best learning experience for every learner. Therefore, to ensure that mathematics learning is taking place, teachers must consider the use of appropriate strategies related to mathematics representation that can fit with the topic being taught.

Impact of Multiple Mathematics Representations

Ozgun-Koca (1998) and Dreher, Kuntze and Learman (2012) came to realize that teachers' knowledge of the use of multiple representation strategies in teaching mathematics produces significant outcomes for students. According to Ozgun-Koca (1998), the use of multiple representations in the teaching and learning of mathematics is a major theme in mathematics education that has increased significantly in importance in recent decades. It is also regarded as the promotion of the learners' competencies and hence should be considered a fundamental goal in the mathematics classroom (Dreher, Kuntze and Lerman, 2012). Therefore, effective mathematics teachers can create a better learning environment using multiple representations to help students have meaningful mathematics learning.

Multiple representations strategy is observed to be important in helping students to grasp well abstract concepts of mathematics. According to the National Council of Teachers of Mathematics (NCTM, 2000) representation is for supporting students' understanding of mathematical concepts and relationships in communicating mathematical approaches, arguments, and understanding to one's

self and to others and in applying mathematics to realistic problem situations through modeling (p.67). Learners need to acquire skill of translating mathematics representation from one mode to another mode in order to be successful in learning mathematics (Mainali, 2021). It is therefore essential for students to learn how to interpret mathematics concepts and ideas involved in different ways of representation.

Multiple representations are a tool for simplifying the action of teaching and learning mathematics. Among the identified reasons for using multiple representations were to concretize mathematics concepts, to simplify the understanding of some mathematics concepts that are directly related to representations, to reduce the difficulty for students in learning some mathematics concepts, and to attract, build interest and motivate students to learn mathematics (Dufour-Janvier, Bednarz & Belanger, 1987). Considering the students' individual differences, multiple representations can play a great role as it enriches the design learning opportunity (Dreher, Kuntze, & Lerman, 2015). In this case, mathematics teachers cannot escape the use of multiple representations during the teaching and learning of mathematics since learning mathematics helps students become more creative through their thinking capacity when solving mathematics problems.

Methodology

Research Design

This study used the quasi-experimental design of a non-equivalent (pre-test and post-test) control group. According to Creswell (2014), this design uses experimental and control groups of which both groups take a pre-test and post-test; however, only the experimental group receives treatment. Particularly, the study considered the learning of mathematics using multiple representation strategies as treatment provided to the experimental group.

Population and Sampling Technique

Four out of sixteen public secondary schools located in the urban district of Unguja Island were randomly selected. Two of these schools were assigned as the experimental group while the other two were the control group. The participants of this study were students from level three who were sampled based on the type of group to which the school is assigned. Table 1 shows the distribution of the number of students based on each type of group.

Table 1: Distribution of the Number of Students in Four Schools

Type	Groups	School	No of students	Total
Experimental	A	A1	26	52
		A2	26	
Control	B	B1	30	74
		B2	44	

Instruments and Validation

Achievement tests (pre-test and post-test) based on mathematics topics of relation and function were used as an instrument for data collection. The test consisted of two sections. The first section involved nineteen objective questions where students were supposed to choose the correct answer and fill in the correspondence letter in brackets. The second section consisted of three questions, which required students to answer in short forms. In all two sections, students were measured on their abilities to explain the concept of relation and functions in a different form of representation and to be able to relate the concepts to real-life situations.

Hence the test was composed of questions that demanded students to identify relations and functions in different ways of presentations (such as ordered pair, pictorial, graphical, inequality, and equation) to identify the domain and range of relations and functions in different ways of presentation and to identify various real-life statements which represented relations or functions. To ensure validity, the test was well prepared by researchers and reviewed by mathematics experts considering its matching with the objectives of the treatment. The instrument was also piloted, after which the reliability was checked using a test-retest reliability coefficient, and the result was found to be 0.9 indicating quite high reliability (Ary, Jacobs, Sorensen, & Razavieh, 2010).

Data Collection Procedure

The study started by observing the real situation in classrooms. This observation was used as the baseline information to determine the teaching strategies utilized by mathematics teachers during the process of teaching and learning mathematics. It

was observed that most of the teachers used a single method of teaching with a single way of representing the concept. The achievement test was then given to the students to measure their scores and to acquire the results that can be used to check for the students' equivalence in their mathematics achievement scores between two groups of experimental and control. As reflected in table 2, the pre-test was done before training the teachers of the experimental group on the use of multiple representation strategies in classroom practice. The teachers in the assigned experimental group were then provided with training in the use of multiple representations strategy during their lessons. The training focused on encouraging teachers' use of multiple representations for presenting concepts. Teachers who were not trained formed the control group. These teachers were left to continue teaching the same topic using other teaching strategies. It is after the implementation of what has been trained for teachers under the experimental group that researchers were able to collect post-test for students of both two groups.

Table 2: Data Collection Procedure based on the Designed Experiment

Type of group	Topic field	Pre-test	Intervention	Post-test
Experimental	Relations and Functions	□□□□□□□□	Use of multiple representations strategies	□□□□□□□□
Control	Relations and Functions	□□□□□□□□	Other strategies	□□□□□□□□

Table 3: Descriptive Statistics of the Achievement Test for Two Groups

Pre-test score	**N**	**Mean**	**Std. Deviation**
Experimental group	52	30.7885	12.56097
Control group	74	31.527	13.7594
Post-test score	**N**	**Mean**	**Std. Deviation**
Experimental group	52	40.1923	12.85826
Control group	74	31.9459	10.46965

Table 4: Independent t-test

	F	**t**	**Df**	**Sig(2-tailed)**
Pre-test	1.846	-.307	124	.759
Post-test	.474	3.959	124	.000

Statistical Treatment of Data

Data was analyzed quantitatively where both descriptive and inferential statistics were used. Through descriptive analysis of data, the mean and standard deviation of the achievement score in both pre and post-test were obtained for both the experimental and the control groups. On the other hand, inferential statistics was used whereby an independent t-test and paired sample t-test were calculated to observe the differences.

Results and Discussion

This section presents the results based on data analysis. It was guided by research questions as follows.

Research Question 1: Is there a significant difference in the score of the experimental and the control groups before and after the intervention?

The research question called for testing of the following null hypothesis: there is no significant difference in the score of the experimental and the control groups before and after the intervention.

Table 3 and 4 show the results of the analysis of mathematics achievement scores for students in both groups before and after the intervention.

Table 3 shows that the mean and standard deviation obtained as a result of the pre-test were *M=30.79, SD= 12.56097* for the experimental group and *M=31.527, SD=13.7594* for the control group. The Sig of .759 for the pre-test shows no significant

difference between the experimental and the control groups. The results obtained from the post-test in table 3 indicate that the mean and standard deviation for the experimental group were *M=40.1923, SD= 12.85826* and for the control group were *M=31.9459, SD=10.46965*. The Sig of .000 for the post-test shows a significant difference between the experimental and the control groups, the experimental group performing higher than the control group. Therefore, the null hypothesis is rejected since the experimental group performed higher than the control group in the post test period.

The finding from the first research question shows no difference in the students' mean scores on the achievement pre-test between the experimental group and the control group. Additionally, the result of the independent t-test showed no significant difference between the pre-test scores of students in the experimental groups and students in the control group. This finding implies that the two groups were equivalent with the same level of using a single strategy in classroom practices. These results agreed with the study of Moh'd, Uwamahoro, Nzotungicimpaye & Orodho (2021) who revealed that the use of a single representation strategy in the process of teaching and learning mathematics was commonly observed by most of the teachers in the classroom practice. Hence, they recommended for mathematics teachers be provided with in-service training in order to enrich them with different types of knowledge including those of representations and strategies.

Research Question 2: Is there a significant difference in the mathematics achievement scores of the experimental group before and after the treatment?

Having established that the experimental group performed higher than the control group after the intervention, it was necessary to determine the difference in the performance of the experimental group before and after the intervention. Therefore, the research question called for testing of the following null hypothesis: there is no significant difference in the mathematics achievement scores of the experimental group before and after the treatment.

Table 5: Descriptive Statistics for the Experimental group before and after Treatment

Post-test score	N	Mean	Std. Deviation
Before Intervention	52	30.7885	12.56097
After Intervention	52	40.1923	12.85826

Table 6: Paired Sample t-test for the Experimental Group

	t	df	Sig. (2-tailed)	Effect size
Paired Sample t-test	-4.243	51	.000	.261

As seen in table 5, the mean score for the experimental group prior to the intervention was 30.7885 and the mean score after the intervention was 40.1923. The Sig of .000 in table 6 is lesser than the critical value, suggesting that the difference between the pre-test and the post-test in the experimental group is statistically significant. Therefore, the null hypothesis is rejected and we maintain that the multiple representations strategies used in the experimental group during the intervention session yielded better results and therefore are more effective in the achievement of students compared to other strategies used in the control group.

The significant difference in the mean scores in student achievement between the experimental group and the control group at the post-test session implies that the multiple representation strategy is a more effective approach in teaching mathematics for better student achievement. This is supported by the study of Moh'd, Uwamahoro, Nzotungicimpaye, & Orodho (2021 which argued that the use of multiple representation strategies in teaching mathematics provides the opportunity for teachers to consider the learners' diversity in terms of their characteristics and level of understanding. They recommended teachers' use multiple representation strategies so as to enhance students' deep understanding of the content and to build the competence of students of different capacities and personalities. Therefore, the strategies introduced

in the experimental group give a positive impact to the achievement of students.

Conclusions and Recommendations

The study concludes that using multiple representation strategies used in the experimental group during the intervention period caused a significantly higher achievement for students. Therefore, the study recommends that mathematics teachers should implement multiple representation strategies during their mathematics teaching. Teachers should be provided with in-service training on the proper utilization of varieties of representation strategies in teaching and learning mathematics for better results to be realized.

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