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Impact of the activity and reality principles on learners' achievement regarding systems of linear equations

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ABSTRACT

This article reports the impact of incorporating the activity and reality principles of realistic mathematics education (RME) when teaching systems of linear equations (SLE). The impact is considered in relation with learners' achievements. A quantitative approach typified by a quasi-experimental design with non-equivalent groups was followed. 50 grade 10 learners of secondary school mathematics participated in the study. 26 of these composed the control group while 24 consisted of the experimental group. The study site was conveniently chosen while participants were randomly assigned to both groups after pre-testing. Treatment was an approach, which included the reality and activity principles of RME to teach SLE. By contrast, the control group was taught in a conventional manner. Data were collected through pre-testing and post testing. Post-treatment analyses such as the ANOVA test showed that there was a significant difference in achievement between the experimental and the control groups. In this regard, learners who were taught based on a method that included the activity and reality principles achieved higher scores than the group, which learned through conventional teaching methods. This finding demonstrates that integrating the activity and reality principles of RME in the teaching of SLE can contribute to learners' high achievement. It is therefore recommended that mathematics teachers should integrate RME principles in their teaching as a way of enhancing learners' performance in mathematics topics.

Keywords: systems of linear equations, realistic mathematics education, reality principle, activity principle, achievement

INTRODUCTION

Mathematics plays a vital role in life through its contributions to social, economic, scientific, and technological advancement in nations of the world. Moreover, the study of mathematics can provide personal satisfaction. However, it is not everyone who enjoys studying the subject, for example, some school learners consider mathematics to be a difficult subject. The difficulty experienced by learners is at times reflected in their performance in mathematics assessments. In Zambia, which is the country, where the current study was conducted, the performance of candidates in mathematics has been historically poor (Ministry of Education (MOE), 2013a). Although it cannot be said that leaners' poor performance in mathematics is a direct consequence of ineffective teaching, we hold an anecdotal view that such a relationship exists. The presumed relationship has in the recent past given impetus, partially though, to research studies, which focus on prospective mathematics teachers' conceptual understanding of mathematics concepts, which they are expected to teach (Malambo, 2020, 2021; Malambo et al., 2018, 2019). Reported through such studies are not solely findings concerning mathematics student teachers' superficial understanding of mathematics concepts but embedded too are quests for strategies to enhance effective teaching of mathematics. It is effective teaching of mathematics, among others, which is anticipated to contribute to a reversal of candidates' high failure rate in school mathematics national examinations.

Zambian stakeholders' determination to improve the quality of mathematics education in the country has previously led to undertakings such as a comprehensive review of the school curriculum (MOE, 2013a). Inclusively, the initiative to place emphasis on values, skills and knowledge when teaching mathematics topics was provided for MOE (2013b). Complementary efforts by the Zambian Ministry of Education to improve learners' achievement include a recommendation for teachers to promote socio-constructivist teaching/learning environments in which learner-centered teaching methods are applied (MOE, 2013a). However, these endeavors have not yet yielded expected results in that learner achievement in mathematics is reportedly still unimpressive (Examinations Council of Zambia (ECZ), 2015, 2016, 2018).

Mathematics education literature provides an evolving and domain-specific instruction theory titled realistic mathematics education (RME) whose origin is in Netherlands (Van den Heuvel-Panhuizen & Drijvers, 2014). This theory seems to correspond with the recommendation in the Zambian curriculum to teachers to facilitate active engagement of learners during the teaching/learning process (MOE, 2013a). Besides, international research findings suggest that instruction based on RME is more effective than one premised on conventional teaching methods where a teacher dominates classroom discourse (Ozdemir & Uzel, 2011). Equally, significant improvements have been reported concerning learners' achievement when RME is utilized as a basis for teaching mathematics (Zakaria & Syamaun, 2017).

Much of the current form of RME is derived from the view that mathematics must not be perceived as subject matter to be transmitted, but rather as a human activity connected to reality and relevant to society (Freudenthal, 1977). RME is conceptualized to provide guidance regarding how children learn mathematics and likewise how mathematics should be taught (Van den Heuvel-Panhuizen, 1996). Van den Heuvel-Panhuizen (2000) typifies RME by six adapted principles namely, activity, reality, level, inter-twinement, interaction, and guidance principles. For purposes of our study, we chose to focus on the activity and reality principles in the context of teaching systems of linear equations (SLE). This preference was due to the two principles' substantial consequences for RME assessment (Van den Heuvel-Panhuizen, 1996). Most importantly, these two principles seem to be consistent with the aspiration in the (Zambian curriculum) to actively involve learners and link mathematics to real-life (MOE, 2013a).

Logically, the persistent dismal performance of Zambian learners in mathematics assessments is an aggregation of learners' performance in questions representing different topics of the syllabi. Although there are several topics in the syllabi (MOE, 2013b), the choice of SLE arises from an understanding that they lend themselves to application and have connectivity with real life problems. These characteristics of SLE are arguably inclined to the reality principle. The reality principle entails that a learner should not start with abstractions and definitions for later application but should instead begin with problems in 'rich' contexts eliciting mathematization (Freudenthal, 1968, 1979 as cited by Van den Heuvel-Panhuizen, 2000). Included in the reality principle is the issue of learners' abilities to "apply mathematics in solving 'real-life' problems" (Van den Heuvel-Panhuizen & Drijvers, 2014, p. 523). In this regard, Van den Heuvel-Panhuizen (2000) contends that reality principle "is not only recognizable at the end of the learning process in the area of application, [but] reality is also conceived as a source for learning mathematics" (p. 5). The viewpoint is that mathematizing reality should result into learning of mathematics in the same way mathematization of reality resulted into mathematics. Guidance to promote learner active participation (MOE, 2013a), corresponds with the activity principle, which requires learners to be considered as active participants and not receivers of ready-made mathematics in the learning process. What this suggests is that mathematics is learned by 'doing' mathematics (Van den Heuvel-Panhuizen & Drijvers, 2014). This principle is consistent with scenarios of allowing learners to be confronted with problem situations, which enable them to develop by themselves different mathematical tools and insights (Van den Heuvel-Panhuizen, 2000).

The scenario discussed earlier regarding Zambian learners' poor performance in examinations and assumed relationship between teaching and leaners' performance provided a basis for our current investigation. While the positive influence of RME teaching approaches towards learners' achievement have been affirmed in other countries, no study has previously been conducted in Zambia to validate such findings. It is also necessary to mention that international studies seem to have utilized overall RME approaches in contrast with the current study, which narrows the focus to two specific principles of RME. To determine the effect of incorporating the activity and reality principles in the teaching of SLE, the following research question guided the study: What is the impact on learners' achievement of integrating the activity and reality principles of RME into the teaching process of SLE? The preceding research question is addressed through the testing of the ensuing null hypothesis, which was correspondingly formulated: There is no significant difference in effectiveness as it relates to learners' achievement between a teaching method incorporating the activity and reality principles of RME and traditional teaching methods. In the next section, we provide methodological considerations relating to this study.

METHODOLOGY

This study was intended to establish the impact on learners' achievement of integrating activity and reality principles of RME in the teaching of SLE. A quasi-experimental design with non-equivalent groups was used (Cohen et al., 2007). The choice of the design was guided by a desire to use existing school classes so that learning is not disrupted. Further, the design was ideal for intact groups, which are normally assumed to have similar achievement levels.

Two groups namely, experimental and control were organized and studied. The main difference between the experimental and control groups hinged on the teaching methods employed to teach SLE. Learners in the experimental group were taught using an approach epitomized by the reality and activity principles of RME (Van den Heuvel-Panhuizen, 2000), therein also called a treatment. In alignment with the features of the activity and reality principles, the teaching/learning starting point for learners in the experimental group was normally to allow them to tackle SLE in the context of real-world problems. The problems involved among others issues of prices and weights of items in the school tuck-shop inclusive of ages of the learners. Sub-groups of learners in the experimental group regularly and actively engaged in various strategies to solve mathematics problems involving SLE. Those activities resulted into class presentations, discussions, and comparisons of the sub-groups' answers. By contrast, the control group was taught using a traditional method through which the teacher explained fixed procedures such as the substitution method to solve SLE. Thus, solutions to SLE mathematics problems were provided by the teacher after which learners wrote exercises based on the work covered. Occasionally, word mathematics problems were presented to the control group, and such were deemed as applications of the concept learnt. The following is an example of the activities that learners in the experimental group undertook:

Table 1. Synopsis of the research process

Group	Pre-test	Intervention	Post-test
Control	Achievement test	Conventional	Achievement test
Experimental	Achievement test	RME principles	Achievement test

> A group of learners was asked to visit a school tuck shop to observe the arrangement of drinks and biscuits on the shelves. An interesting scenario was reported to the experimental class that soft drinks and biscuits had price tags under. The arrangements depicted only two price tags under the items. Further, the arrangement showed that two biscuits and two soft drinks cost a total of 44 Zambian Kwacha whereas three soft drinks and one biscuit cost a total of 30 Zambian Kwacha. Groups of learners within the experimental class were then assembled and requested to suggest strategies for determination of the price of one drink and one biscuit. At the end of the groups' investigations, representatives of groups were asked to make presentations concerning the strategies and thereafter whole class discussions ensued.

Similarly, the following typifies questions for the control group during the teaching/learning process:

> Use substitution method to solve $x+y=17$, $x-y=3$

Furthermore, **Table 1** provides a synopsis of the research process.

The population involved all grade 10 learners of mathematics at a single secondary school in one of the 10 provinces of Zambia. Convenience sampling (Gravetter & Forzano, 2012) was used to select the province and school due to accessibility. The sample was composed of 50 grade 10 learners of mathematics at the chosen school (those who finally participated at post-test stage). Of the 50 learners, 24 constituted the experimental group while 26 made up the control group. These groups were assembled from the already existing classes in the school. Grade 10 was chosen as it is an entry level into senior secondary school in the Zambian school system. By design the grade 10 learners were not yet exposed to SLE at senior secondary level except for their encounter with the topic at junior secondary school.

Document analysis was part of the development process of the draft achievement test (ECZ, 2016; Kalimukwa et al., 1995; MOE, 2013b; Redspot, 2013). For the achievement test, we as researchers concerned ourselves with content validity. In this regard, the achievement test was prepared using adapted questions from past examinations of the (examining body) and those from the recommended mathematics secondary school textbooks. The view was that such questions had already gone through the rigor of development. Prior to the commencement of the study, a pilot study was successfully conducted comprising of learners with similar characteristics to those in the actual sample. The purpose of the pilot study was to refine the data collection instruments. Hence, a reliability test was performed and the Cronbach's alpha (α) coefficient for test scores was calculated. Cronbach's alpha coefficient of 0.60 for the achievement test was recorded and this score suggested that the instrument was reliable. Moreover, expert judgements on the draft achievement test were sought from experienced teachers of mathematics. The teachers accordingly confirmed that the instrument had content validity.

Pre-testing and post-testing based on SLE were conducted on both the experimental and control groups. Pre-testing was done to guarantee similarity of ability in participants of both groups at the beginning of the study. After application of the treatment to the experimental group and teaching of control group using conventional methods, a post-test was administered to both groups. The purpose was to determine the effect of the treatment on learners' achievement. Data were organized using Microsoft Word and Excel and thereafter analysed using SPSS version 25.0 for Windows. The data were tested for normality and likewise the homogeneity test was conducted. A one-way ANOVA test was performed at 0.05 level of significance in respect of the null hypothesis and in the context of the research question.

The study's theoretical bases anchored partially on positivism whose claim is that "science provides man with the clearest possible ideal of knowledge" (Cohen & Manion, 1989, p. 12). Ideas of social constructivism (Adams, 2006) were also upheld. Overall, in this study we championed a pragmatist orientation, which goes with the idea of embracing what works (Creswell, 2012). The thrust of our study is acquisition of meaningful learning, which is conceptualized to manifest when problems or ideas presented to learners are connected to what they already know. We upheld social constructivism because of its consistency with situations where learners socially and actively construct knowledge and personal meanings unlike in scenarios where they only memorize concepts verbalized by teachers. For social construction of meanings, it is necessary that the material studied gets linked to learners' experiences in real life. Such learning experiences are likely to elicit curiosity, which is a form of motivation.

RESULTS

Results presented in this section are generally consistent with the following null hypothesis, which was formulated correspondingly with the study's research question: There is no significant difference in effectiveness as it relates to learners' achievement between a teaching method incorporating the activity and reality principles of RME and traditional teaching methods. At the pre-testing stage, 25 learners composed the experimental group while 30 learners were in the control group. However, during post-testing one learner and four learners in the experimental and control groups respectively had withdrawn from the study.

The findings of the normality test, which was conducted using the Shapiro-wilk test revealed that the p-value of the pre-test scores for the control group was 0.743 while that of the experimental group was 0.471. The p-values associated with the post-test

Table 2. Descriptive statistics aligned with the post-test

Group	Group	n	Mean
Post-test	Experimental	24	82.1
	Control	26	56.4

Table 3. ANOVA of post-test results

Variance	SS	df	MS	F	Sig.
Between groups	8,242.093	1	8,242.093	99.402	0.000
Within groups	3,979.987	48	82.916		
Total	12,222.080	49			

for the control and experimental groups were 0.796 and 0.941 respectively. Clearly, these p-values are greater than the alpha value (α=0.05). Conclusively, the test scores were approximately normally distributed suggesting that the assumption of normality was met.

Levene test was performed with an objective of testing the datasets for homogeneity. The idea was that of fulfilling the requirement for performing ANOVA test. Results of the Levene test indicated that the p-value for the pre-test scores was 0.838 while the p-value of the post-test scores was 0.704. These results reveal that the p-values were greater than α=0.05. This confirms that there was no significant difference in variance between the experimental and control groups. It was concluded that the variance in test scores were assumed to be the same for the two groups. Since datasets were approximately normally distributed and the variances were assumed to be equal, ANOVA test was used.

Results Aligned with the Pre-Test

After administration of the pre-test, both descriptive statistics and a one-way ANOVA were conducted to compare the achievement levels of learners in the control and experimental groups. Descriptive statistics associated with the pre-test showed that each of the 30 pupils who initially composed the control group scored an estimate of 30.4% (SD=15.3). Each one of the 25 pupils in the experimental group achieved an estimated score of 30.0% (SD=14.7). These results are indicative that the achievement levels of the learners between the two groups were similar before the administration of the treatment (intervention). One-way ANOVA pre-test results showed that the p-value between groups was 0.921. Considering that this p-value is greater than 0.05 the hypothesis that the groups are not significantly different was not rejected. Accordingly, at α=0.05 level of significance there was no significant difference between the experimental and control group (at pre-testing phase).

Results Aligned with the Post-Test

To determine the impact of the intervention on learners' achievement, testing was conducted in relation with the null hypothesis. Initially, the post-test scores were analyzed using descriptive statistics and then ANOVA was performed. Descriptive statistics are shown in **Table 2** while ANOVA results are depicted in **Table 3**.

Based on **Table 2**, the post-test scores' descriptive statistics indicate that the experimental group performed better than the control group with mean scores of 82.1% and 56.4% respectively. Likewise considering **Table 3**, ANOVA post-test results revealed a p-value of sig.=0.000, which is less than the alpha value (α=0.05). This means that there was a significant difference in achievement between the control group and the experimental group after the treatment, which was administered to the experimental group. By implication, that result necessitated the rejection of the null hypothesis.

DISCUSSION

Examination of the computed statistics confirms that the achievement levels between the experimental and control group differed meaningfully after the treatment was applied. It was established that at α=0.05 level of significance, there was a statistically significant difference between the scores of the experimental and control groups. Particularly, the findings indicate that the achievement scores of learners improved significantly when SLE were taught using a method that utilized the activity and reality principles of RME. Thus, statistical evidence points to the fact that compared to learners who were taught SLE based on a traditional teaching method, learners who were taught using a strategy premised on the two RME principles achieved higher scores. This is a demonstration that learners who are actively involved in a learning process, which includes mathematizing real life situations (Freudenthal, 1968, 1979 as cited by Van den Heuvel-Panhuizen, 2000), are more likely to register improved performance.

Achievement levels in the experimental group were higher than those of learners in the control group probably because experimental learners did not memorize SLE procedures, but rather constructed the concepts through active participation. Learners did not begin with definitions of SLE through predetermined procedures of solving SLE but had opportunities to learn with problems in 'rich' contexts (Van den Heuvel-Panhuizen, 2000). The learners in the experimental group had opportunities to discuss with their group members. Additionally, they often shared ideas and opinions with peers; a practice, which could have deepened their conceptual understanding. Such opportunities were not prevalent during the teaching process of the control group. The control group experienced the SLE via teacher dominated teaching methods. Although methods such as teacher exposition have their place in the teaching of mathematics, they are more likely to encourage memorisation of concepts than to facilitate in-depth understanding. The finding of our study confirms that teaching methods based on RME principles do influence learners' understanding of mathematics concepts more than those in which a teacher dominates the teaching and learning processes. This inference corroborates previous research in which it is suggested that RME compared with conventional teaching methods does improve learners' achievement (Ozdemir & Uzel, 2011; Zainil, 2017; Zakaria & Syamaun, 2017).

CONCLUSION

In this article, our objective was to answer the research question: What is the impact on learners' achievement of integrating the activity and reality principles of RME into the teaching process of SLE? Concerning this question, it has been established that there is a positive impact on learners' achievement when SLE are taught using a method that integrates the activity and reality principles of RME. Specifically, there is a comparatively significant improvement in achieved scores of learners in SLE when the activity and reality principles of RME constitute a teaching method. Although the findings of this study are in the context of SLE, they broadly speak to the usefulness of integrating principles of RME in the teaching and learning process. Arguably, in countries such as Zambia, where candidates perform poorly in examinations (ECZ, 2015, 2016, 2018), incorporation of RME principles in the teaching of mathematics could contribute towards improvement of learners' achievement scores in mathematics topics.

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Ethical statement: All procedures defined by institutional and national ethical standards were followed during the study. Participants were briefed about the study and their participation were strictly voluntary. The right to withdraw from the study at any time was explained, and confidentially and anonymity assured. Informed consents of the participants were obtained.

Declaration of interest: No conflict of interest is declared by authors.

Data sharing statement: Data supporting the findings and conclusions are available upon request from the corresponding author.

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