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GRADE 10 NAMIBIAN LEARNERS' PROBLEM-SOLVING SKILLS IN ALGEBRAIC WORD PROBLEMS

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ABSTRACT

This study investigated Grade 10 Namibian learners' problem-solving skills in algebraic word problems. A sample of 351 Grade 10 learners from ten secondary schools in the Ohangwena Region in Namibia participated in this study. The study followed a qualitative approach and adopted Polya's Problem-Solving Model as the framework. The data were collected using the Algebra Word Problem-solving Test and Interview. The findings showed that the learners needed better problem-solving skills in algebraic word problems. Only 6% and 7% of the learners showed an ability to understand the problems and devise a plan, respectively, while only 5% could carry out the plans. Based on the findings, it is recommended that teachers introduce learners to Polya's steps of problem-solving and incorporate word problems into mathematics teaching.

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1. INTRODUCTION

Problem-solving skills refer to the ability to use specific approaches and strategies to arrive at a meaningful solution(s) to a situation or problem (İncebacak & Ersoy, 2016). This requires the ability to identify the nature of a problem, deconstruct it (break it down), and design an effective set of activities to handle the obstacles associated with the problem (Abazov, 2016). Problem-solving skills are important in both school and real-life situations. It is posited that a person with problem-solving skills develops into a self-confident, creative, and autonomous thinker (Yöyen et al., 2017). Great problem solvers strive to discover and understand the underlying causes of a difficult situation; the essence of a specific problem that can be recognised, addressed, and finally, resolved (Al-Mutawah et al., 2019).

When the educational policy for independent Namibia was formulated in 1996, the Ministry of Education instucted that "the Namibia National Curriculum Guideline should provide opportunities for developing essential problem-solving skills in grade 10–11 mathematics curriculum" (National Institute for Educational Development, 2016, p. 46). However, problem-solving skills cannot be developed in isolation; instead, they must be developed across the mathematics curriculum for Namibian learners to improve learners' skills in this regard. The use of word problem-solving activities in mathematics could be one way of developing problem-solving skills.

Mathematical word problems are special types of mathematical problems; they are "verbal descriptions of problem situations; they refer to an existing or imaginable meaningful context; and they can be closed or open, algorithmic or non-algorithmic" (Van Dooren et al., 2019, p. 99). Palm (2006) elaborates that a word problem is a set of sentences that describes a 'real-life' scenario in which a problem must be solved using mathematical calculations. Due to the fact that word problems sometimes incorporate a form of narrative, they are sometimes referred to as story problems, and can vary in terms of the amount of language employed. The use of natural language in mathematics instruction is typically justified in two ways. First, by bringing the actual world into classrooms, word problems aid learners in developing links between the real world and mathematics (Krawitz et al., 2018). Second, some scholars suggest that word problems may provide tangible meaning to abstract mathematical things (Greer et al., 2002).

Several studies show that for many high school learners, solving word problems is one of the biggest challenges in algebra (Bush & Karp, 2013; Capraro & Joffrion, 2006; Jupri & Drijvers, 2016; Van Amerom, 2003). This has been corroborated in Namibia, as some studies have shown that Namibian learners have difficulties when it comes to solving algebra word problems (Albin & von Watzdorf, 2019; Sikukumwa, 2017). As stated in the examiner's reports from 2014 to 2018, algebra word problems were found to be one of the most challenging topics in the Junior Secondary Certificate mathematics examination in Namibia (Directorate of National Examinations and Assessment, 2014, 2015, 2016, 2017, 2018). The reports note that algebra word problems were always poorly addressed. However, the examiner's reports did not specify the learners' skills in solving algebra word problems. It is against this backdrop that this study explored Grade 10 learners' problem-solving skills in algebraic word problems. Specifically, it explored the learners' abilities to understand algebraic word problems, devise a plan to solve the problem, and carry out the plan.

Some scholars have investigated learners' problem-solving skills at various levels of schooling. For example, Lupahla (2014) used Polya's Problem-Solving Model to investigate the algebraic problem-solving skills of Grade 12 learners in the Oshana Region in Namibia. The results show that only 34.6% and 29.1% of the learners, respectively, were successful in the 'understanding the problem' and 'devising a plan' steps of Polya's model. Alternatively, 26.1% and 23.8% learners, respectively, successfully executed the devised plan, and were able to look back at the steps taken and reevaluate if necessary. In a similar study, Lubis et al. (2017) explored junior high school students' problem-solving skills in linear equations and inequalities in one variable using Polya's problem-solving steps. Their study showed that the performance of the students decreased from the first step (understanding the problem) to the third step (carrying out the plan) of the problem-solving process. However, they performed better in the last step (looking back) than in the second and third steps.

Sipayung and Anzelina (2019) investigated the mathematics problem-solving skills of junior high school learners in Nusantara Lubuk Pakam, Indonesia. The study was based on using a realistic mathematics approach to three aspects of integers (the recognition and comparison of integers, the addition and subtraction of integers, and the multiplication and division of integers). The study showed that the percentages representing the average score of the learners' problem-solving abilities in the four steps were 81.6%, 73.5%, 78.6%, and

76.1% respectively. This finding suggests that using a realistic approach to mathematics teaching augments learners' skills in mathematical problem solving in terms of integers.

Riyadi et al. (2021) conducted a qualitative study to examine learners' problem-solving skills in algebra word problems at third, fourth, and fifth-grade elementary school level in Indonesia using Polya's four-steps model. The study revealed that the learners' problem-solving skills across the grades decreased from the first step (understanding the problem) to the fourth step (looking back). Hendriana et al. (2018) investigated the mathematics problem-solving ability of Grade 12 senior high school learners in Cimahi, Indonesia. The data were collected using a test. The investigation found that the learners' mathematics problem-solving ability was extremely poor, and that the typical learner could not comprehend the problems or express them in mathematical form.

In their study of elementary school teachers' mathematics problem-solving ability in Indonesia, based on Polya's steps, Yayuk and Husamah (2020) found that only 5.3% of the participants were successful at understanding the problem, devising a plan, and carrying out the plan. Only 8% of the teachers were successful in re-checking answers. In general, the study showed that the pre-service teachers had poor mathematics problem-solving abilities, based on Polya's problem-solving steps. A similar study was conducted by Akyüz (2020) to determine pre-service elementary school mathematics teachers' mathematical problem-solving performance in a university using Polya's problem-solving steps. The study showed that the pre-service teachers' performance decreased from the first step to the fourth step of Polya's steps, and that the overall problem-solving performance level was low. In general, most of the studies highlighted here, and many more (e.g., Aljaberi, 2015; Hijada Jr & Cruz, 2022; Pentang et al., 2021) suggest that most students, at different school levels, have poor mathematical problem-solving abilities.

This study was framed using Polya's (1945) Problem-Solving Model. The model consists of four steps: understanding the problem, devising a plan, carrying out the plan, and looking back. This study focused on the first three steps. Understanding the problem refers to people's ability to figure out what is being asked, what is known, what is not known, and what type of answer is required (Polya, 1957). Individuals are able to understand a problem when they are familiar with the relevant vocabulary, when they know what the question is asking for (required or unknown), and know what information is in the problem (given or known) to help them solve it. This first step concerns comprehending the problem's given circumstances and limitations, expanding on the objective and the unknown, and making the required assumptions (Schoenfeld, 2014). Understanding the problem is a key part of finding the solution to the problem. In other words, before a problem can be solved, the problem solver must understand the problem (Berlinghoff & Gouvêa, 2021; Niss & Højgaard, 2019; Polya, 1981).

Lee (2016) highlights that in the 'understanding the problem' step, Polya proposes that teachers should first ask learners questions, for example: Do you understand all the terminologies used to denote the problem? Could you repeat the problem in your own words? Can you think of an image or a diagram that would help you understand the problem? What is it that you are required to do or find? What unknowns are there? And, what information is missing or required, if any? According to Daulay and Ruhaimah (2019), understanding the problem is split into two phases: getting to know the problem, and searching for a greater understanding. The phase of getting to know the problem is where a problem solver can restate the problem in their own words, while the phase of searching for a greater understanding is where the problem solver can identify what is required (what is unknown or what you are required to find) and known information (the given information that can help you to solve the problem).

Devising a plan refers to coming up with a way (translating the problem) to solve the problem by setting up an equation, drawing a diagram, and making a chart (Polya, 1957; Wickramasinghe & Valles, 2015). Ersoy (2016) points out that at the stage of devising a plan, learners are supposed to choose which actions, such as computation, sketching, and so on, to perform to attain the desired result.

Nurkaeti (2018) states that, in order for a problem solver to solve a problem successfully, the person should formulate a plan, which could be in the form of a drawing or a math-based solution to the problem; and figure out the concepts of the question, formula, or mathematical ideas that will be used to solve the problem. Polya mentions that there could be many ways to solve a rational problem. The best way to develop the ability to choose an effective plan is for learners to solve as many problems as possible (Maulyda et al., 2019). Learners will find it increasingly convenient to choose a proper plan to solve a problem once they are exposed to different problems. A problem solver is said to have a plan when he/she knows what calculations, computations, or constructions they must perform to get the unknown, or at least know the outline. Understanding a problem and coming up with a solution might be a difficult and drawn-out process. However, the main key to solving a problem is to devise a plan. This idea may emerge slowly, after unsuccessful trials and a time of delay, or it may suddenly appear in a flash as a "bright idea" (Polya, 1973, p. 8). A learner may start using one plan and then realise that the plan does not fit the information given or lead to the desired solution. In this case, the learner has to choose a different plan. In some instances, Gray (2018) mentions that a variety of techniques might need to be used in conjunction with the developed plan, such as guessing and checking, looking for patterns, making an orderly list, drawing a picture, eliminating possibilities, using a model, working backward, using a formula, or being ingenious. This will allow learners to solve the given problem and improve their problem-solving skills.

Carrying out the plan is putting the strategy into action by doing any necessary tasks or calculations, carrying out each step of the plan as one goes, and keeping an accurate record of one's work (Polya, 1957). Polya (1973) emphasises that, normally, this step is simpler than devising the plan. All that is needed, in general, is care and diligence as the problem solver should have the expertise needed. Therefore, the problem solver must keep the selected plan in mind at all times and use it. If it does not continue to work, they must discard it and choose another one. In'am (2014) clarifies that 'carrying out the plan' is how a learner or problem solver puts the good plan they have chosen into action. In'am also explains that it does not help to understand a problem and devise a good plan to solve it if the plan is not implemented. Instead, an effort should be made to put the plan into action. According to Lupahla (2014), once a problem has been carefully scrutinised and a plan has been developed, assuming the plan is appropriate for the problem, carrying out and implementing the plan will be a fairly simple process. Putting the plan into action can be viewed as a mathematical operation that must be performed to obtain the result of completion (Nurkaeti, 2018).

Polya (1945) referred to 'looking back' as revisiting the completed answer, and evaluating and re-examining the result, as well as the road that led to it. Chang (2019) defines looking back as a reflection process in problem solving. It is the process of looking over the results, verifying the solution against the problem, comparing the problem with the offered solution, comparing the mathematical terms in the problem with the answer, and being confident in the response provided (Nurkaeti, 2018).

2. METHOD

This research employed a qualitative approach and descriptive research design. The participants comprised 351 learners from ten sampled secondary schools in the Ohangwena region, Namibia. All 351 learners wrote an algebra word problem-solving test, while 20 randomly selected learners (two from each school) were interviewed after the test. The test was not time constrained; the learners were allowed to submit their scripts when they felt that they had attempted the questions to the best of their abilities. This was done to enable the learners to demonstrate all of their knowledge and skills in solving the problems. The test and interview questions were developed by the first author with the guidance of the Namibia Senior Secondary Certificate Grade 10 – 11 mathematics syllabus, and Polya's Problem-Solving Steps. The test comprised six algebraic word problems (see Figure 1).

1) Frans and Meke are friends. Frans took Meke's mathematics test paper and will not tell her what mark she got. Frans knows that Meke doesn't like word problems, so he decided to tease her with word problems. Frans says: "I have 2 marks more than you do and the sum of both our marks is equal to 14." What are their marks?

2) A father is three times as old as his son, and his daughter is 3 years younger than his son. If the sum of their ages 3 years ago was 63 years, find the present age of each.

3) A 1 litre bottle of mango juice costs N$2.00 more than a 1liter bottle of strawberry juice. If 3 bottles of mango juice and 5 bottles of strawberry juice cost N$ 78.00, determine the price of each juice per 1 litre bottle.

4) Natalia thought of a number. She doubled the number, then subtracts 6 from the result and divides the answer by 2. The quotient will be 20. What is the number?

5) In a physics quiz you get 2 points for each correct answer. If a question is not answered or the answer is wrong, 1 point is subtracted from your score. The quiz contains ten questions. Hafo-Letu received 8 points in total. How many questions did Hafo-Letu answer correctly?

6) On a farm Tulukeni has goats and chickens. His son counted 70 heads and his daughter counted 200 legs. How many chickens and goats does Tulukeni have?

Figure 1. Algebra word problem solving test questions

The interviews were semi-structured in nature, and were used to further explore the learners' understanding of the problem, devising a plan, and carrying out the plan in solving the test questions. Some of the questions asked at the interviews were: "Restate the problem (question) in your own words", "how did you approach the problem?", "What did you do to solve the problem?", and "are there any steps that you know or used to solve the problem?"

The learners' solutions to the test questions were deductively analysed and categorised using a modified rubric adapted from Charles et al.'s (1987) and Sumaryanta's (2015) problem-solving analysis rubrics. For the 'understanding the problem' category, the sub-categories were: 'identified all knowns and unknowns', 'identified some knowns and unknowns', 'identified no known or unknown,' and 'did not attempt the question'. For the 'devising a plan' category, the sub-categories were: 'the statement is translated into a correct algebraic form', 'the statement is translated into a partially correct algebraic form', 'the statement is translated into an incorrect algebraic form,' and 'no translation of the statement'. For the 'carrying out the plan' category, the sub-categories were: 'correct procedures and correct answer', 'correct procedures and incorrect answer', 'incorrect procedures and correct answers,' and 'wrong procedures with the wrong answers or problems not attempted'. An interpretive data analysis process was used to make sense of the learners' responses to the interview questions.

3. RESULT AND DISCUSSION

3.1. Result

The findings are presented according to the first three steps of the Polya Problem-Solving Model explored in this study.

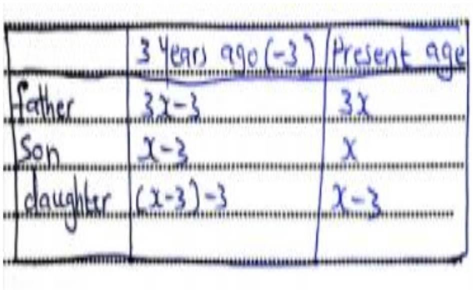
Understanding the problem

Table 1 shows the learners' performance in the 'understanding the problem' step in all six test questions. The table shows that most of the learners - an average of 260, or 74% - were not able to identify the known or unknown conditions in the problems.

Table 1. Descriptive statistics of the learners' performance in understanding the question

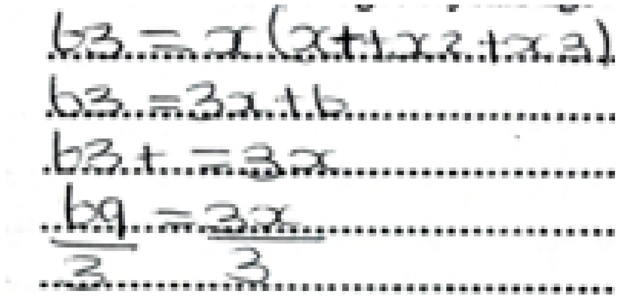
	Identified all knowns and unknowns	**Identified some knowns and unknowns**	**Identified no known or unknown**	**Did not attempt the question**
Q1	36	89	222	4
Q2	6	63	282	0
Q3	31	72	245	3
Q4	21	94	235	1
Q5	3	39	308	1
Q6	21	61	266	3
Mean	20	70	260	2

An average of 70 learners (20%) partially identified the known or unknown, while only an average of 5.6% (20 learners) showed an understanding of the problems by identifying all known and unknown terms in the questions. Some learners' understanding of the problem presented in Question 2 is shown in Figure 2.



(a)
All known and unknown identified

(b)
Known or unknown partially identified



(c)
No known or unknown identified

Figure 2. Examples of learners' solutions showing their understanding of question 2

The learner in Figure 2(a) identified the present ages of the father, son, and daughter, as well as their ages in the past three years. In Figure 2(b), the learner only identified the present age of the son. The learner used different variables to identify the different ages of the father, son, and daughter, which made it difficult to solve the problem. The learner in Figure 2(c) could not identify the unknown and the known in the question. Most of the learners had similar solutions to the problems, showing a lack of understanding of the questions.

Furthermore, the interview revealed that most of the learners lacked an understanding of the questions. One of the learners interviewed said, "…I seriously don't understand this question. Once I realised the question was tricky, I just tried my best to do some calculations. I'm just not sure if it's correct or not." Even when the learners were able to restate the problem in their own words during the interview, most of them could not identify the given information from the problems.

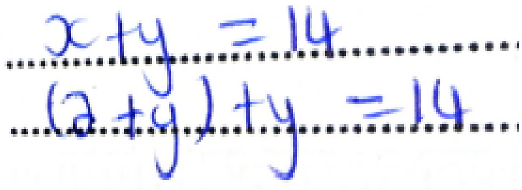
Devising a plan

The descriptive statistics of the learners' performance in devising a plan are presented in Table 2. The table shows that most of the learners could not devise a plan to solve the problem as, on average, 260 (74%) of them translated the problems into incorrect algebraic forms; and, on average, only 24 (approximately 7%) of them successfully devised plans to solve the problems by translating them into the correct algebraic equations.

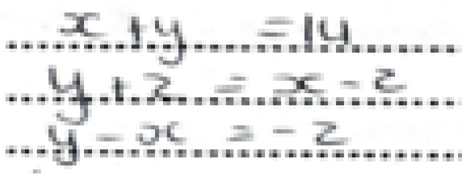
Table 2. Learners’ performance in devising a plan (N =351)

	Statement is translated into a correct algebraic form	**Statement is translated into a partially correct algebraic form**	**Statement is translated into an incorrect algebraic form**	**No translation of the statement at all**
Q 1	33	97	217	4
Q 2	14	64	273	0
Q3	36	51	261	3
Q 4	30	93	227	1
Q 5	3	44	303	1
Q 6	30	37	281	3
Mean	24	64	260	2

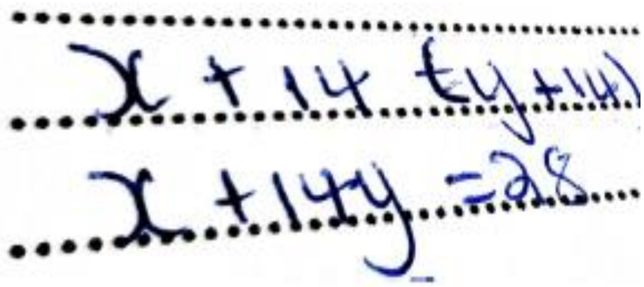
Figure 3 shows how some learners devised a plan to solve Question 1. The learner in Figure 3(a) translated the problem statement into the correct algebraic representations; x + y = 14 and (2 + y) + y = 14.



(a)
Algebraic statement translated into correct algebraic form



(b)
Algebraic statement translated into partially correct algebraic form



(c)
Algebraic statement translated into an incorrect algebraic form

Figure 3. Examples of learners’ devised plans to solve question 1.

The learner in Figure 3(b) translated the problem statement into a partially correct x + y = 14, continuing to write another expression, y + 2 = x - 2, which leads to y - x = -2, which is wrong. Alternatively, the learner in Figure 3(c) translated the statement into an incorrect x + 14 (y + 14), following this up with x + 14y = 28, which does not make sense.

During the interview, only five learners out of the 20 interviewed said that they had deduced the formulae or equations to answer the problems presented. The remaining 15 learners explained that they simply solved the problems by guessing the answers. This further demonstrates that most of the learners could not devise a plan for solving algebraic word problems.

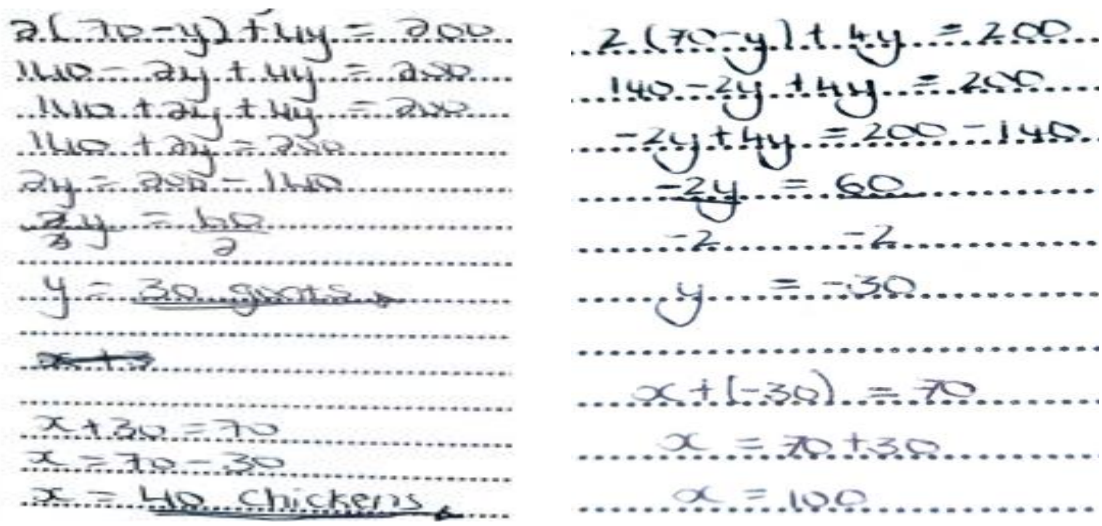
Carrying out the plan

Table 3 shows the learners' overall performance in the step of carrying out the plan across all six test questions. Most of the learners, 283 (81%), on average, followed incorrect procedures to arrive at incorrect answers in their attempt to solve the problems. A few leaners (18, accounting for 5%) used incorrect procedures, but got the final answeres correct. Only 17 learners (approximately 5%) used the correct procedure to get the correct answers to the questions. In all questions, the overwhelming majority of the learners' (between 70% – 95%) did not use a correct procedure to attempt any of the questions.

Table 3. Learners' performance in carrying out the plan (N =351)

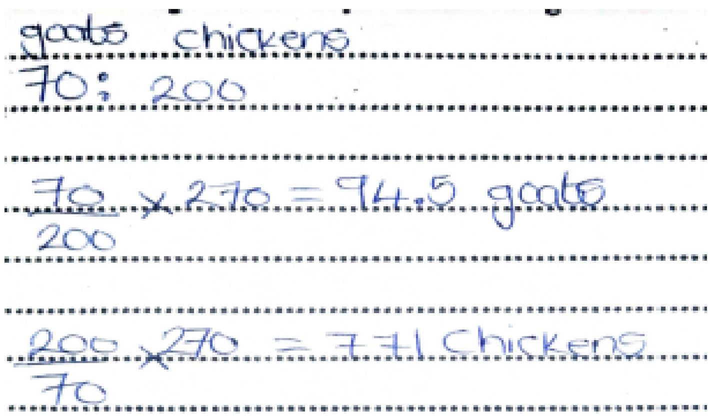
	Correct procedures and correct answers	**Correct procedures and incorrect answers**	**Incorrect procedures and correct answers**	**Wrong procedures with the wrong answers or problems not attempted**
Q 1	34	72	13	232
Q 2	5	24	13	309
Q3	27	14	12	298
Q 4	24	36	40	251
Q 5	1	18	14	318
Q 6	12	34	13	292
Mean	17	33	18	283

Some examples of how the learners carried out their plan to answer Question 6 are shown in Figure 4. The learner in Figure 4(a) showed an ability to carry out the devised plan to solve the problem.



(a) Correct procedures and correct answer

(b) Correct procedures and incorrect answer



(c)
Incorrect procedure and answer

Figure 4. Examples of learners' work on carrying out the plan for question 6

The learner in Figure 4(b) used the correct procedure, but made an incorrect calculation that led to the incorrect answer. Figure 4(c) shows a learner who used incorrect procedures and got an incorrect answer. Most of the learners did not seem to have followed a well-defined plan for solving the problem, as confirmed in the interview. One of the learners replied, "I just did my calculation," when asked if he followed any specific steps in solving the problem. Another learner stated, "I just guessed by putting the numbers on one side and the letter (variables) on the other side of the equal sign". When further asked if she used any equation or formula to solve the problem, the student asked, "Equation from where? No, there were no equations given in my paper". In general, the step of carrying out a devised plan was not successfully performed as most of the learners solved the problems without following any derived plan, resulting in incorrect steps being followed to solve the problems.

3.2. Discussion

The study revealed that the learners had poor mathematical problem-solving skills concerning understanding a problem. Most of the learners could not identify the known(s) and unknown(s) of the algebraic word problems. This finding corroborates those of Hendriana et al. (2018), Lupahla (2014), and Yayuk and Husamah (2020). Furthermore, it was found from the interview that although some learners could state the problem in their own words, only a few could identify the known and what was asked. This is in alignment with Peterson et al.'s (2017) finding that most learners find it difficult to understand mathematical word problems and communicate their views in writing. Similarly, in their study, Kusumadewi and Retnawati (2020) concluded that learners' problem-solving ability was low due to their difficulty locating keywords from the problems. This resulted in learners guessing the solution without completing the process. Some learners failed to restate the problem in their own words since they did not understand the question. Learners' reading skills are a crucial element of problem solving (Steinbrink, 2009); it may be the case that some of the learners were not able to read and understand the questions due to literacy problems. This concurs with Meutia et al.'s (2020) observation that the learners in their study could not express their understanding of the problems by restating the questions.

In addition, it was found that most of the learners in the current study were not able to devise a plan to solve the algebraic word problems. This finding aligns with those of previous studies, for example, those of Hendriana et al. (2018), Lupahla (2014), and Yayuk and Husamah (2020). This is not surprising because most of the learners did not show any understanding of the problems, which is the foundation for devising and caring out a plan. Brijlall (2015) notes that learners' challenges in understanding mathematical problems prevent them from taking the essential measures to solve these problems. If a learner does not know what the question is asking, it will be difficult for them to come up with a plan that can be used to solve the problem. Similarly, Nikmah et al. (2019) have noted that learners have difficulties identifying the known and unknown(s) in the first step, making it difficult for them to come up with an effective plan that will allow them to solve the problem.

Furthermore, the study found that the learners' overall performance in carrying out a plan was dismal. This might be because most of the learners could not establish a plan to solve the problems. This is in agreement with that of Franestian et al. (2020), who find that students' performance in carrying out a plan was poorer than their performance in the first two stages. A similar finding was also made by Khabibah et al. (2018), who showed that the students in their study could not implement a plan to solve the given problems.

In general, the learners' problem-solving performance decreased from the first step of the Polya Problem-Solving Steps to the third step, as was found in other studies (Akyüz, 2020; Lubis et al., 2017; Lupahla, 2014; Riyadi et al., 2021). This buttresses the hierarchical nature of Polya's Problem-Solving Steps in that success in subsequent steps depends much on success in the preceding steps of the problem-solving process. As noted by Tambychik and Meerah (2010), if the first two steps of the problem-solving process are challenging for learners, the third step, and consequently the fourth step, will also be challenging.

4. CONCLUSION

One of the main goals of 21st Century education is the development of learners' problem-solving skills (Gunawan et al., 2020; Kivunja, 2015; Rahman, 2019). In Namibia, promoting learners' mathematical problem-solving skills is a key issue in the school curriculum. However, research on Namibian learners' mathematical problem-solving skills is sparse. Therefore, this study investigated Grade 10 Namibian learners' problem-solving skills in algebraic word problems. It was found that the learners' problem-solving skills in algebraic word problems, specifically concerning understanding the problem, devising a plan, and carrying out the plan, were extremely poor. In addition, it was found that the learners' problem-solving performance decreased from the first step of Polya's Problem-Solving Steps to the third step.

One way of improving learners' computational skills at primary and secondary school level is by using didactical games (Hooshyar et al., 2021; Yeh et al., 2019). We recommend that mathematics teachers in Namibia incorporate educational games into their mathematics instruction to enhance learners' computational skills. To enhance learners' understanding of mathematical word problems, which was found to be a major problem for the learners in this study, we recommend that when teaching mathematical word problems, teachers should include the translation of mathematical word problems from English (the Language of Teaching and Learning) to the native language of the learners, and vice versa, before translating the problems into algebraic form. In addition, we recommend that teachers model Polya's Problem-Solving Steps when teaching algebra word problems in particular, and mathematics in general.

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