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Secondary school students' attitude towards mathematics word problems

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Students' positive attitude towards mathematics leads to better performance and may influence their overall achievement and application of mathematics in real-life. In this article, we present the findings of an investigation on students' attitude towards linear programming (LP) mathematics word problems (LPMWPs). An explanatory sequential quasi-experimental design involving a pre-intervention-intervention-post-intervention non-equivalent control group was adopted. A sample of 851 grade 11 Ugandan students (359 male and 492 female) from eight secondary schools (public and private) participated. Cluster random sampling was applied to select respondents from eight schools; four from central Uganda and four from eastern Uganda. The attitude towards mathematics inventory-short form (ATMI-SF) was adapted (with $\alpha = 0.75$) as a multidimensional measurement tool for measuring students' attitude towards LPMWPs. The results revealed that students' attitude towards LPMWPs was generally negative. Enjoyment, motivation, and confidence were weekly negatively correlated while usefulness was positively correlated. Additionally, the results found no significant statistical relationship between students' attitudes towards LPMWPs and their age, gender, school location, school status, and school ownership. The discrepancy is perhaps explained by both theoretical and/or psychometric limitations, and related factors, for instance, students' academic background, school characteristics, and transitional beliefs from primary to secondary education. This study acknowledges the influence of and supplements other empirical findings on students' attitude towards learning mathematics word problems. The present study provides insight to different educational stakeholders in assessing students' attitude towards LPMWPs and may provide remediation and interventional strategies aimed at creating students' conceptual change. The study recommends that teachers should cultivate students' interests in mathematics as early as possible. Varying classroom instructional practices could be a remedy to enhance students' understanding, achievement, and, motivation in learning mathematics word problems. The teachers' continuous professional development courses should be enacted to improve instruction, assessment, and students' attitude. Overall, the study findings support the theoretical framework for enhancing the learning of mathematics word problems in general and LP in particular.

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Introduction

The term attitude is not a new concept in mathematics education. It has been defined by different authors in different settings and contexts. For instance, Aiken (1970) defined attitude as "a learned disposition or tendency on the part of an individual to respond positively or negatively to some object, situation, concept or another person" (p. 551). According to Lin and Huang (2014), attitude towards mathematics can be referred to as positive, negative, or neutral feelings and dispositions. Attitude can be categorized as bi-dimensional (person's emotions and beliefs) or multidimensional (affect, behavior, and cognition). Over the last decades, an extensive body of research from different settings and contexts have investigated variables that influence students' attitude towards Science, Technology Engineering and, Mathematics (STEM) (e.g., Aiken, 1970; Gardner, 1975; Kempa and McGough, 1977). In this study, we are particularly concerned with students' attitude towards mathematics word problems, and linear programming (LP) in particular due to the significant roles LP plays in constructing models for understanding the three (STE).

Numerous studies have been published on students' attitude towards mathematics, which is always translated as liking and disliking of the subject (Arslan et al., 2014; Davadas and Lay, 2020; Pepin, 2011; Utsumi and Mendes, 2000). To some secondary school students, mathematics appears to be abstract, difficult to comprehend, sometimes boring, and viewed with limited relationship or relevance to everyday life experiences. At primary and secondary school levels, students start well but gradually start disliking mathematics feeling uncomfortable and nervous. Consequently, they may lack self-confidence and motivation during problem-solving. To some students, persevering and studying advanced mathematics has become a nightmare. Indeed, some students do not seem to know the significance of learning mathematics beyond the compulsory level. Students may (or may not) relate mathematical concepts beyond the classroom environment if they have a negative attitude towards the subject. This may lead to their failure to positively transfer mathematical knowledge and skills in solving societal problems.

Mathematicians have attempted to research and understand affective variables that significantly influence students' attitude towards mathematics (e.g., Barmby et al., 2008; Davadas and Lay, 2020; Di Martino and Zan, 2011; Evans and Field, 2020; Grootenboer and Hemmings, 2007; Hannula, 2002; Maamin et al., 2022; Marchis, 2011; Pongsakdi et al., 2019; Yasar, 2016; Zan et al., 2006). Some researchers have gone ahead to ask fundamental questions on whether or not students' attitude towards mathematics is a general phenomenon or dependent on some specific variables. To this effect, some empirical findings report students' attitude towards specific units or topics in mathematics aimed at enhancing the learning of specific mathematical content and mathematics generally (e.g., Arslan et al., 2014; Estrada and Batanero, 2019; Gagatsis and Kyriakides, 2000; Julius et al., 2018; Mumcu and Aktaş, 2015; Selkirk, 1975; Townsend and Wilton, 2003).

Rather than investigating students' general attitudes toward mathematics, recent research has also attempted to identify background factors that may provide a basis for understanding students' attitude towards mathematics. Thus, students at different academic levels may have a negative or positive attitude towards mathematics due to fundamentally different reasons. Yet, other studies show the existence of a positive relationship between attitude and achievement in mathematics (e.g., Berger et al., 2020; Chen et al., 2018; Davadas and Lay, 2020; Grootenboer and Hemmings, 2007; Hwang and Son, 2021; Lipnevich et al., 2011; Ma, 1997; Maamin et al., 2022; Mazana et al., 2018; Mulhern and Rae, 1998; Opolot-okurut, 2010; Sandman, 1980; Tapia, 1996). From the above studies, it appears that multiple factors ranging from students' to teachers' classroom instructional practices may influence students' attitudes towards, and achievement in mathematics.

Ugandan context

In Uganda, studies on predictors of students' attitude towards science and mathematics are scanty. There are no recent empirical findings on secondary school students' attitude towards Mathematics and mathematics word problems in particular. Solving LP tasks (by graphical method) is one of the topics taught to 11th-grade Ugandan lower secondary school students (NCDC, 2008, 2018). Despite students' general and specific learning challenges in mathematics and LP, the objectives of learning LP are embedded within the aims of the Ugandan lower secondary school mathematics curriculum (Supplementary Appendix 3). Some of the specific aims of learning mathematics in Ugandan secondary schools include …enabling individuals to apply acquired skills and knowledge in solving community problems, instilling a positive attitude towards productive work…" (NCDC, 2018). Generally, the learning of LP word problems aims to develop students' problem-solving abilities, application of prior algebraic concepts, knowledge, and understanding of linear equations and inequalities in writing models from word problems, and real-life-world problems. Despite the learning challenges, the topic of LP is also aimed at equipping learners with adequate knowledge and skills for doing advanced mathematics courses beyond the 11th-grade (locally called senior four) minimum mathematical proficiency at Uganda Certificate of Education (UCE).

However, every academic year, the Uganda National Examinations Board (UNEB) highlights students' strengths and weaknesses in previous examinations at UCE. The consistent reports (e.g., UNEB, 2016, 2018, 2019, 2020) on previous examinations on the work of candidates show that students' performance in mathematics is not satisfactory, especially at the distinction level. In particular, the above previous examiners' reports show students' poor performance in mathematics word problems. The examination reports have consistently revealed numerous students' specific deficiencies in the topic of LP (please see Supplementary Appendix 1). Students' challenges in LP mainly stem from comprehension of word problems to the formation of wrong linear equations and inequalities (in two dimensions) from the given word problems in real-life situations. Thus, wrong models derived from questions may result in incorrect graphical representations, and consequently wrong solutions and interpretations of optimal solutions. These challenges (and others) may consequently hinder and/or interfere with students' construction of relevant models in science, mathematics, and technology. Moreover, learners have consistently demonstrated cognitive obstacles in answering questions on LP, while the majority elude these questions during national examinations by answering questions from presumably "simpler" topics. Noticeably absent in all the UNEB reports are factors that account for students' weaknesses in learning LP and the specific interventions to overcome students' challenges. Some students have, however, developed a negative attitude towards the topic. Yet, students' attitudes may directly impact their learning outcomes (Code et al., 2016).

Although some empirical findings (e.g., Opolot-okurut, 2010) have reported on students' attitude towards mathematics in the secondary school context, this paper presents results from a more specific investigation into students' attitudes towards mathematics word problems. Specifically, the present study investigated secondary school students' attitude towards solving linear programming mathematics word problems (LPMWPs). This is because studies concerning attitudes towards and achievement in mathematics have begun to drift from examining general attitudes to a more differentiated conceptualization of specific students' attitude formations, and in different units (topics). Although different attitudinal scales (e.g., Code et al., 2016; Fennema and Sherman, 1976; Tapia, 1996) were developed to measure different variables influencing students' attitudes towards mathematics, this study specifically investigated the influence of some of these constructs on students' attitude towards learning LP. According to the above-stated authors (and other empirical findings), students' attitude is a consequence of both general and specific latent factors.

Mathematics word problems

Verschaffel et al. (2010) define word problems as "verbal descriptions of problem situations wherein one or more questions have raised the answer to which can be obtained by the application of mathematical operations to numerical data available in the problem statement." The authors categorized word problems based on their inclusion in real-life world scenarios. Thus, mathematics word problems play significant roles in equipping learners with the basic knowledge, skills, and, understanding of problem-solving and mathematical modeling. Some empirical findings (e.g., Boonen et al., 2016) show that mathematics word problems link school mathematics to real-life world applications. However, the learning of mathematics word problems and related algebraic concepts is greatly affected by students' cognitive and affective factors (Awofala, 2014; Jupri & Drijvers, 2016; Pongsakdi et al., 2019). Mathematics word problems are an area where the majority of students experience learning obstacles in secondary schools and beyond (Abdullah et al., 2014; Awofala, 2014; Dooren et al., 2018; Goulet-Lyle et al., 2020; Julius et al., 2018; Pearce et al., 2011; Sa'ad et al., 2014; Verschaffel et al., 2010, 2020a, 2020b). By contrast, comprehension of mathematics word problems explains relational difficulties. Consequently, this has undermined students' competence, confidence, and achievement in word problems and mathematics in general.

Yet, mathematics word problems are intended to help learners to apply mathematics beyond the classroom in solving real-life-world problems. Verschaffel et al. (2020a, 2020b) and Boonen et al. (2016) have argued that mathematics word problems are difficult, complex, and pause comprehension challenges to most learners. This is because word problems require learners to understand and apply previously learned basic algebraic mathematical principles, rules, and techniques. Indeed, most learners find it difficult to understand text in word problems before transformation into models. This is partly due to variations in their comprehension abilities and language (Strohmaier et al., 2020). Consequently, learners fail to write required mathematical algebraic symbolic operations and models. Yet, incorrect models lead to wrong algebraic manipulations and consequently wrong graphical representations and solutions.

Notably, research findings by Meara et al. (2019), and Evans and Field (2020) indicate that students' mathematical inefficiency is due to their transitional epistemological and ontological challenges from primary to secondary education. Other studies (e.g., Georgiou et al., 2007; Grootenboer and Hemmings, 2007; Li et al., 2018; Norton, 1998; Sherman, 1979; Sherman, 1980) attribute students' poor performance and achievement in mathematics to gender differences. Thus, students may start learning mathematics well from primary but gradually lose interest in some specific units and finally in mathematics generally. For the case of LP, and as indicated above, it is likely that students' attitude towards mathematics and equations, inequalities, and LP in particular gradually drop in favor of other presumably simpler topics. However, to boost performance in mathematics word problems, Goulet-Lyle et al. (2020) proposed a step-by-step problem-solving strategy to enhance mastery and develop a positive attitude towards learning.

Students' attitudes should, therefore, be investigated as well as their influence on their conceptual changes. Several empirical studies have also investigated the relationship between attitude towards, and achievement in mathematics across all levels, and in different contexts (e.g., Bayaga and Wadesango, 2014; Camacho et al., 1998; Chun and Eric, 2011; Davadas and Lay, 2020; Karjanto, 2017; Khavenson et al., 2012; Ozdemir and Ovez, 2012; Quaye, 2015; Selkirk, 1975; Tahar et al., 2010; Utsumi and Mendes, 2000; Yáñez-Marquina and Villardón-Gallego, 2016). In particular, these studies generally focused on students' attitude towards mathematics, and many of them were conducted from the western context (Kasimu and Imoro, 2017). Yet, students may have different perceptions and attitudes towards specific content (topics) in mathematics irrespective of their setting, context, and learning environment.

To enhance mathematical conceptual proficiency, educators should target and/or boost students' cognitive and affective domains in specific mathematics content. In a related genre, students' proficiency in LP word tasks may largely depend on their prior algebraic knowledge, skills, and experiences. Julius et al. (2018) noted that prior conceptual understanding coupled with students' attitudes towards solving algebraic concepts impacted students' inherent procedures in writing relational symbolic mathematical models (inequalities) from word problems, and provision of correct numerical solutions. Despite numerous difficulties encountered by students in algebraic inequalities as reported in Fernández and Molina (2017), Molina et al. (2017), Bazzini and Tsamir (2004), Tsamir and Almog (2001), Tsamir and Bazzini (2004, 2006), and Tsamir and Tirosh (2006) have suggested a combination of approaches, methodologies, and strategies than applying one specific method. Adopting this instructional and assessment approach may help to overcome students' learning and related algebraic challenges, which are all aimed at enhancing the learning of mathematics.

The theoretical framework

This study is situated on the theoretical framework according to constructivism, and Eccles, Wigfield, and colleagues' expectancy-value model of achievement motivation (Wigfield, 1994; Wigfield and Eccles, 2000). The expectancy-value model is based on the expectancy-value theories of achievement. Thus, the theory is based on the premise that success on specific tasks and the values inherent in those tasks is positively correlated with achievement, and consequently students' attitude towards specific mathematical tasks. In the context of the attitude towards mathematics inventory-short form (ATMI-SF), the theory combines motivation, enjoyment, confidence, value (usefulness), and related latent variables to explain students' success in learning mathematics. Constructivism is a form of discovery learning that is based on the premise that teachers facilitate learning by actively involving learners so that they construct their world knowledge and understanding based on individual prior experiences and schema (Olusegun, 2015; Ültanır, 2012). Thus, previous knowledge, understanding, and reflection with new knowledge are inevitable for supporting subsequent learning and acquisition of both conceptual and procedural knowledge. These knowledge components may later arouse learners' attitude towards specific mathematics content and mathematics achievement generally.

We are particularly concerned about students' efforts, and persistence, their perceived difficulties and related challenges in learning LPMWPs and the experiences learners may encounter when solving LP word tasks. Empirical findings and our own experiences as mathematics educators show that students' challenges in LP largely depend on their insufficient previous algebraic knowledge and experiences in applying the knowledge of equations and inequalities. In this article, we discuss students' attitude towards LPMWPs using the expectancy-value model theory within the constructivism paradigm. Using this paradigm helped to explain the ATMI-SF constructs and their significance in enhancing the learning of mathematics in secondary schools. The expectancy-value theory and constructivism have been widely applied to enhance the learning of mathematics and science (Awofala, 2014; Fielding-Wells et al., 2017; Meyer et al., 2019; Wigfield and Eccles, 2000; Yurt, 2015). To foster a positive attitude, teachers (educators) should assign different tasks to students based on their academic level so that they apply previously acquired knowledge, understanding, and experiences in subsequent learning. Stein et al. (2000) reasoned that students' proficiency and competency are determined by the mathematical tasks they are given. Tasks at the lower cognitive stage (memorization level), for example, must be different from those at the highest cognitive level (doing mathematics). In the context of learning LP, students should first understand and appropriately apply the basic knowledge of equations and inequalities to adequately and proficiently solve non-routine LPMWPs.

Attitude towards mathematics and the learning of linear programming word problems

Linear programming is one of the algebraic topics that require students' understanding of basic mathematical principles and rules before the application of computer software for solving and optimizing more advanced and complex LP problems. Linear programming is a classical unit, "the cousin" of mathematics word problems, which has gained significant applications in mathematics, science, and technology (Aboelmagd, 2018; Colussi et al., 2013; Parlesak et al., 2016; Romeijn et al., 2006) because the topic is used for formulating models that link theoretical to practical mathematical applications. Thus, LP provides basic elementary modeling skills (Vanderbei, 2014).

Previous empirical studies have revealed that LP and/or related concepts are not only difficult for learners but also challenging to teach (Awofala, 2014; Goulet-Lyle et al., 2020; Kenney et al., 2020; Verschaffel et al., 2020a, 2020b). Different factors account for learners' challenges in mathematics word problems (e.g., Ahmad et al., 2010; Haghverdi et al., 2012; Heydari et al., 2015). The challenges range from students' comprehension of word problem statements, and their attitude towards the topic, to their transformation from conceptual to procedural knowledge and understanding. Learners' attitude towards solving algebraic word problems should, therefore, be investigated and integrated during classroom instruction to help educational stakeholders provide appropriate and/or specific instructional strategies and remedies.

Several attitudinal scales (with both cognitive and behavioral components) have been developed (Lim and Chapman, 2013; Yáñez-Marquina and Villardón-Gallego, 2016) adopted or adapted (Lin and Huang, 2014) to assess students' attitude towards mathematics and in specific mathematics content. For instance, Geometry Attitude Scales (Avcu and Avcu, 2015), Statistics Attitude Scales (Ayebo et al., 2019; Khavenson et al., 2012), Attitudes toward Mathematics Word Problem Inventory (Awofala, 2014), the Attitude towards Geometry Inventory (ATGI) instrument (Utley, 2007), and others. In this study, we adapted the ATMI-SF instrument (Lin and Huang, 2014) to investigate the 11th-grade students' attitude towards learning LP word problems (see Supplementary Appendix 1). Taken together, research shows that a high percentage of educational stakeholders around the world are concerned about attitude towards mathematics and word tasks in particular. However, to fully understand students' attitude towards mathematics, it is necessary to investigate beyond general mathematics attitudes and examine specific underlying aspects of these attitudes. Thus, the present study examines students' attitude towards solving LP mathematics word problems.

Methodology

This study investigated students' attitude towards linear programming mathematics word problems (LPMWPs). To achieve this purpose, a quantitative survey research design was used (Creswell and Plano Clark, 2018). The authors contend that the quantitative approach provides a more general understanding of the views of participants in an entire population. Thus, this approach was applied to collect, analyze, and describe the secondary school students' ATLPWPs, their experiences, and latent behavior.

Research design

The present study was part of a large study that investigated the effect of active learning heuristic problem-solving approach on students' achievement and attitude towards learning LP word problems. The present study adopted a quantitative approach to gain a deeper and broader understanding of students' ATLPWPs (Creswell, 2014; Creswell and Plano Clark, 2018; Djamba and Neuman, 2002). A quasi-experimental pre-test, post-test, and non-equivalent control group study design was adopted. By using the stated approach and design, researchers ably compared and contrasted students' ALPMWPs. Learners from the experimental group, and in their intact classes participated. The main reason for adopting intact classes was to avoid interference with the internal school-set timetables and already set operational schedules.

The sample

The analysis reported in this study comprised a research study of 851 grade 11 students from eight randomly selected private or public secondary schools (both rural and urban), four from Mbale district, eastern Uganda, and the remaining four from Mukono district, central Uganda. Cluster random sampling was used to select regions and schools. The sampled schools were allocated to the experimental and comparison groups by a toss of a coin. Four hundred thirty-two (50.8%) students were assigned to the comparison group while four hundred nineteen (49.2%), were assigned to the treatment group. Two schools from both regions were assigned to the experimental group. The selection of students from the two distant schools within/outside the regions and assigning them to treatment groups was to avoid spurious results. In a situation where a particular school had more than one class ("stream"), at the time of data collection, at least one hundred students were randomly picked from different classes in that specific school to respond to the attitudinal questionnaires. The main reason for selecting the 11th-grade students as research participants are based on curriculum materials in which LP is taught to the 11th-grade students (see NCDC, 2018). Indeed, at the time of data collection, students were preparing for UCE national examinations for the 2019/2020 academic year. The school heads revealed that the mathematics syllabus containing LP word problems (Supplementary Appendix 1) had been completed. The students were selected to provide their experiences and attitudes toward learning LP word problems. Of the 851 students who participated, 359 (42.2%) were males and 492 (57.8%) were females with a mean age of 18.32 (S.D. = 0.94) years. We predicted that the participants had adequate knowledge and understanding of solving LP word problems by graphical method. Identification numbers were allotted to participants before they anonymously and voluntarily completed adapted ATMI-SF questionnaire items.

Research instruments and procedure for administration

In addition to demographic questions, the ATMI-SF (Lin and Huang, 2014), a 14-item instrument questionnaire consisting of four subscales (enjoyment, motivation, value/usefulness, and self-confidence) was adapted to measure students' attitude towards learning LP mathematics word problems. The ATMI-SF is a 5-point Likert-type scale with response options ranging from "Strongly Disagree (1)" to "Strongly Agree (5)." The ATMI-SF items were developed by Lim and Chapman (2013), which were also developed and validated from several mathematics attitudinal questionnaire items (Fennema and Sherman, 1976; Kasimu and Imoro, 2017; Mulhern and Rae, 1998; Primi et al., 2020; Tapia, 1996). The ATMI-SF was adapted because it directly correlates with the learning of LP, "the cousin of mathematics word problems." English is the language of instruction in Ugandan secondary schools' curricula, and translation of questionnaire items was not required. The content validity of the questionnaire was assessed by three experts (one senior teacher for mathematics, one senior lecturer for mathematics education, and one tutor at a teacher training institution). The experts were selected based on their vast experience in teaching mathematics at various academic levels. The experts further evaluated the appropriateness and relevance of the adapted questionnaire items. Based on their recommendations, suggestions, and comments, some questionnaire items were adjusted to suit students' academic level and language to adequately measure students' ATLPMWPs.

To adequately implement active learning heuristic problem-solving strategies, teachers from the treatment group were trained. First, students' basic prior conceptual knowledge of equations and inequalities plus the basic algebraic principles and understanding were reviewed to link previous concepts to the learning of LP. Second, several learning materials were applied to help students adequately master the concepts. The materials included the use of graphs, grid boards, excel, and GeoGebra software. These strategies were further integrated with problem-solving strategies (Polya, 2004) by ensuring that students understand the LP word problem, devise a plan, adequately carry out the plan and finally look back to verify solution sketches and procedures. To ensure that students minimize errors and misconceptions, the learning of LP was further integrated with Newman Error Analysis (NEA) model prompts. The teachers emphasized question reading and decoding, comprehension, transformation, process skills, and encoding to cultivate students' positive attitude towards LPMWPs.

The procedure and data analysis

The ATLPMWP questionnaires were completed by individual students at their respective schools in their natural classroom settings. The 11th-grade students completed this study in at most 20 min on average. The survey contained a 'filter statement', as a Social Desirability Response (SDR) to verify and discard respondents' questionnaires, especially those who did not read (see item 15 in Supplementary Appendix 1) or finish answering questionnaire items (Bäckström and Björklund, 2013; Latkin et al., 2017). Written consent was received from all participants and participation in this study was completely voluntary and confidential. Participants who felt uncomfortable completing the questionnaire were not penalized. Data were collected with the help of mathematics heads of the department who were selected from sampled schools as experts. Participants were explained, the purpose of the study before administering and/or filling in questionnaire items. In the presence of the principal researcher, research assistants, and some selected school administrators, participants completed and returned all the questionnaires. In addition to the administration of questionnaire items, 12 heads of department and 24 students (a boy and a girl from each sampled school) were interviewed to correlate the data collected in trying to adequately assess the learning of LP word problems. Descriptive and inferential statistics were used to analyze the collected data about the background characteristics. Data were analyzed using the Statistical Package for Social Sciences (SPSS) version 26. In addition, and where necessary, excerpts were used to make a judgment about students' ATMWPs, and how this affects the learning and achievement in mathematics and LP in particular.

Preliminary results and interpretation

Psychometric properties of the ATLPMWP scale. IBM SPSS (version 26) software package was used for analysis. Preliminary statistical analysis revealed no evidence of missing data due to a few cases, which were ignored because they did not exceed 5% of sample cases (Barbara and Tabachnick, 2001; Kline Rex, 1998; Lim and Chapman, 2013). However, out of 885 questionnaires distributed, 31 questionnaires were removed because the participants did not either conform to SDR (Bäckström and Björklund, 2013; Latkin et al., 2017) or had incomplete data. Univariate analysis was run to examine the degree of normality (Hair et al., 2010; Pallant, 2011). The indices for skewness and kurtosis were within the acceptable ranges (±2 and ±7 respectively) (Byrne, 2010; Curran et al., 1996; Hair et al., 2010). Thus, data were fairly normally distributed (Table 1). Exploratory factor analysis was run using initial pilot data collected from 215 students outside the study sample to check the correlation between the items. Most of the ATMI-SF scale inter-item means were below 3.0; suggesting that students generally had negative attitude ALPMWPs. However, browsing through the data, psychometric average scores for items still confirmed and indicated that most students (both male and female) irrespective of the school type and location had a negative attitude towards learning LP word problems (albeit their agreement and consideration that LP is useful).

Factor analysis was performed to confirm the factor structure. Principal component (with varimax) analysis to was used to show interrelationships (Tabachnick, 2001; Pallant, 2011; Pituch, 2016). Four constructs with eigenvalues greater than 1 accounted for 55.89% of the total variance. All items loaded significantly on four factors (enjoyment: 0.91, motivation: 0.89, value/usefulness: 0.94,

Table 1 Descriptive statistics for students' attitude towards linear programming word problems by item.

	N	Mean	S.D.	Skewness	Kurtosis
Item1	851	4.44	0.63	−0.95	1.20
Item2	851	4.30	0.65	−0.94	2.10
Item3	851	4.32	0.66	−0.98	2.07
Item4	851	4.29	0.69	−1.07	2.18
Item5	851	2.16	0.76	0.55	0.76
Item6	851	1.93	0.86	1.12	1.30
Item7	851	2.07	0.65	−0.07	−0.60
Item8	851	2.18	0.76	0.50	0.63
Item9	851	2.20	0.76	0.46	0.53
Item10	851	2.06	0.70	−0.01	−0.77
Item11	851	1.87	0.70	0.83	1.61
Item12	851	2.06	0.70	−0.04	−0.83
Item13	851	2.07	0.70	−0.01	−0.77
Item14	851	2.04	0.69	0.05	−0.57

Table 2 Descriptive statistics for students' attitude towards linear programming word problems by treatment.

	Experimental group ($n = 432$)				Comparison group ($n = 419$)			
Constructs	Mean	S.D.	Skewness	Kurtosis	Mean	S.D.	Skewness	Kurtosis
Item1	4.43	0.64	−1.01	1.42	4.45	0.62	−0.88	0.96
Item2	4.30	0.64	−0.91	2.41	4.31	0.66	−0.97	1.88
Item3	4.32	0.65	−0.95	2.35	4.33	0.67	−1.01	1.87
Item4	4.29	0.68	−0.99	1.73	4.28	0.69	−1.16	2.61
Item5	2.15	0.78	.61	0.89	2.18	0.74	0.49	0.61
Item6	1.94	0.88	1.11	1.15	1.91	0.85	1.14	1.47
Item7	2.05	0.66	−0.06	−0.68	2.09	0.63	−0.08	−0.52
Item8	2.17	0.77	0.52	0.66	2.18	0.74	0.49	0.61
Item9	2.22	0.77	0.35	0.22	2.17	0.74	0.56	0.92
Item10	2.05	0.70	−0.02	−0.85	2.08	0.71	0.01	−0.69
Item11	1.91	0.71	0.97	2.22	1.83	0.69	0.67	0.86
Item12	2.05	0.70	−0.03	−0.84	2.07	0.69	−0.054	−0.81
Item13	2.05	0.70	−0.03	−0.84	2.08	0.71	0.005	−0.69
Item14	2.06	0.69	0.01	−0.69	2.03	0.68	0.101	−0.43

and self-confidence: 0.95 with $p < 0.05$, respectively). The values obtained were consistent with previous empirical findings (see Lin and Huang, 2014, Awofala, 2014). The Kaiser-Meyer-Olkin measure of sampling adequacy test (KMO) and Bartlett's test of sphericity were conducted. The value of KMO in our analysis was $0.71 > 0.60$, and that of Bartlett's Test was significant ($X^2(760) = 13792.55$, $p < 0.005$) indicating a substantial correlation in the data and an acceptable fit (Nunnally and Berstain, 1994, Pallant, 2011). Following the above recommendations, all items were found to be acceptable with adequate construct validity, internal consistency, and homogeneity. Overall, these items were deemed fit to measure students' ATLPWPs in secondary schools.

Tables 1 and 2 show descriptive statistics (mean, standard deviation, skewness, and kurtosis). Important to note are students' scores on ATMI-SF questionnaires during the pre-test and post-test. The results show no significant differences between the two groups in the pre-test and for the four scales (enjoyment, motivation, usefulness, and self-confidence). Indeed, both experimental and comparison groups were similar during the pre-test. There was however a slight change in students' ATLPWPs due to the intervention administered to students from the experimental group (Table 3). The findings, however, show that students generally had a negative attitude towards learning LP word problems. These findings are consistent with other research studies (e.g., see Awofala, 2014). Thus, the learning of LP word problems and related mathematics concepts should be structured using multiple problem-solving techniques to boost students' understanding and attitude.

From the correlation matrix in Table 4 above, it is evident that most of the inter-item correlations are low. This suggests that the data collected shows students' negative attitude towards LP word problems. Students' responses may have revealed intrinsic traits as far as the learning of LP is concerned. These findings are not in any way different from UNEB annual reports on previous students' performance in the topic of LP. The additional qualitative data collected from senior teachers on why students elude questions on LP during internal and national examinations confirmed our investigations.

The results found no significant statistical difference between students' ATLPMWPs, and their age (Table 5), gender (Table 6), school location (Table 7), school status (Table 8), and school ownership (Table 9).

Table 3 Attitude towards linear programming word problems for experimental group and comparison group.

	Experimental group ($n = 432$)		Comparison group ($n = 419$)	
	Pre-attitude	Post-attitude	Pre-attitude	Post-attitude
Item1	4.43	4.54	4.35	4.37
Item2	4.30	4.39	4.21	4.29
Item3	4.32	4.35	4.13	4.30
Item4	4.29	4.32	4.18	4.21
Item5	2.15	3.04	2.08	2.09
Item6	1.94	2.25	1.81	1.89
Item7	2.25	2.59	2.22	2.24
Item8	2.77	2.92	2.18	2.55
Item9	2.82	2.85	2.47	2.61
Item10	2.05	2.72	1.98	2.01
Item11	1.91	2.97	1.35	1.27
Item12	2.07	2.13	2.05	2.01
Item13	2.05	2.43	2.08	0.005
Item14	2.06	2.61	2.03	0.101

Discussions, conclusions, and recommendations

This study sought to investigate the 11th-grade Ugandan students' attitude towards LPMWPs. The psychometric properties of the adapted ATMI-SF instrument were found acceptable. We were fundamentally interested in students' motivation, confidence, usefulness, and enjoyment in learning LP, and related mathematics word problems. These were the four main reliable latent dimensions identified through principal component factor analysis to explain the underlying students' attitude towards LPMWPs. At first, students' attitude towards LPMWPs for both groups (comparison and experimental groups) were not significantly different irrespective of the student's age, gender, school status, or school location. These findings show that students generally had negative attitude towards LPMWPs. Yet, Arslan et al. (2014) show that there exists a positive significant relationship between attitude and problem-solving.

Although students' ratings were below the neutral attitude (please see Table 2), they indicated the usefulness of LP in daily life. The experimental group showed a slightly favorable attitude towards LP word problems (Table 3) after an intervention because the active learning heuristic problem-solving instruction was applied compared to students in the comparison group who learned LP conventionally. Face-to-face interviews with some students and teachers have not been provided in this quantitative study. However, a section of students whom we interacted with revealed that LP concepts are more stimulating, require prior conceptual knowledge and understanding of equations and

Table 4 Inter-item correlations of constructs for predicting students' ATLPWPs ($n = 851$).

	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Item1	1.00													
Item2	0.49	1.00												
Item3	0.51	0.98	1.00											
Item4	0.35	0.51	0.52	1.00										
Item5	−0.04	0.04	0.03	0.02	1.00									
Item6	0.02	0.07	0.07	0.06	0.21	1.00								
Item7	−0.04	0.08	0.07	0.03	0.74	−0.15	1.00							
Item8	−0.03	0.05	0.04	0.01	0.96	0.20	0.76	1.00						
Item9	0.02	0.05	0.05	0.10	0.36	0.31	0.13	0.41	1.00					
Item10	0.19	0.16	0.15	0.14	0.16	0.01	0.22	0.16	−0.04	1.00				
Item11	−0.08	−0.09	−0.08	−0.04	0.07	−0.04	0.03	0.07	−0.10	0.11	1.00			
Item12	0.19	0.17	0.15	0.14	0.16	0.01	0.23	0.16	−0.04	0.98	0.10	1.00		
Item13	0.18	0.16	0.15	0.14	0.16	0.01	0.22	0.16	−0.04	0.99	0.10	0.99	1.00	
Item14	0.12	0.12	0.12	0.22	0.05	−0.04	0.12	0.05	0.16	0.33	0.04	0.33	0.35	1.00

Table 5 Shows the relationship between age and students' ALPMWPs.

							95.0% Confidence interval for B	
Model		***B***	**S.E**	**Beta**	***t***	**Sig.**	**Lower bound**	**Upper bound**
1	(Constant)	2.708	0.240		11.277	0.000	2.236	3.179
	Age	0.005	0.013	0.012	0.346	0.730	−0.021	0.030

Table 6 Shows the relationship between gender and students' ALPMWPs.

							95.0% Confidence interval for B	
Model		***B***	**S.E**	**Beta**	***t***	**Sig.**	**Lower bound**	**Upper bound**
1	(Constant)	2.836	.041		68.640	.000	2.755	2.917
	Gender	−0.029	.025	−0.040	−1.158	.247	−0.078	.020

Table 7 Shows the relationship between school location and students' ALPMWPs.

							95.0% Confidence interval for B	
Model		***B***	**S.E**	**Beta**	***t***	**Sig.**	**Lower bound**	**Upper bound**
1	(Constant)	2.773	0.017		161.266	0.000	2.739	2.806
	School Location	0.037	0.025	0.052	1.516	0.130	−0.011	0.086

Table 8 Shows the relationship between school status and students' ALPMWPs.

							95.0% Confidence interval for B	
Model		***B***	**S.E**	**Beta**	***t***	**Sig.**	**Lower bound**	**Upper bound**
1	(Constant)	2.798	0.017		166.072	0.000	2.765	2.831
	School status	−0.016	0.025	−0.023	−0.659	0.510	−0.065	0.032

Table 9 Shows the relationship between school ownership and students' ALPMWPs.

							95.0% Confidence interval for B	
Model		***B***	**S.E**	**Beta**	***t***	**Sig.**	**Lower bound**	**Upper bound**
1	(Constant)	2.787	0.017		166.617	0.000	2.754	2.819
	School ownership	0.009	0.025	0.012	0.357	0.721	−0.040	0.058

inequalities and that these questions are not interesting to learn in comparison to other topics in mathematics. Our findings concord with Chen et al. (2018) who postulated that positive attitude influences early career performance.

The explanation provided indicated that some teachers either teach this topic hurriedly towards national examinations or some of them avoid teaching it completely. This means teachers have not adequately applied instructional techniques and suitable learning materials to fully explain the concepts of LP to the students. However, it was observed that teachers encouraged students to constantly practice model formation from word problem statements to demystify the negative belief that LP word problems are hard for students to conceptualize. Negative beliefs limit students' understanding, thereby making them fear the topic and consequently develop a negative attitude towards learning LP. However, students' attitudes towards LPMWPs from the experimental group slightly improved compared to their counterparts from the comparison group who almost had a similar attitude towards LP before and after an intervention.

Participants from the experimental group and the comparison groups acknowledged the fact that LP is a challenging topic, although they highly recognized its significance in constructing models, and in developing models for optimization in real-life scenarios. The importance of LP rests in its application and thus teachers were tasked to help learners to develop a positive attitude towards, and their conceptual understanding so that they can reason insightfully, think logically, critically and, coherently. The teachers' competence in applying instructional strategies helped learners from the experimental group to gain deeper and broader insight, conceptual and procedural understanding, reasoning, and positive attitude towards LPMWPs. As Mazana et al. (2018) noted, aspects of attitude (motivation, confidence, value, increased anxiety and enjoyment) enhance students' learning and hence performance. The control group, however, in their conventional instruction still perceived LP as one of the hardest topics. A negative attitude was observed in this particular group of students as indicated in the results of most learners' ATMI-SF questionnaires.

Thus, teachers recognized that hard work and application of prior conceptual knowledge and understanding may favorably help students to develop a positive attitude and perform better. Generally, students seemed not to have adequately developed the knowledge of logical thinking and reasoning of basic and prior LP concepts to aid in learning LP. They did not view the learning of LP from a broader perspective beyond passing national examinations at UCE. The results of this study are likely to inform educational stakeholders in assessing students' ATLPWPs and provide remediation and interventional strategies aimed at creating a conceptual change in students' attitudes towards learning LP and related topics. This will further act as a lens in examining the relationships between students' achievement and their attitude toward learning specific mathematics concepts, as indicators of students' confidence, motivation, usefulness, and enjoyment in learning LP word problems and mathematics generally.

The study findings also point to important issues and may provide insight to the educational stakeholders in cultivating an early positive attitude in mathematics, aimed at investigating students' challenges in specific topics from primary to secondary school mathematics. This may be a potential strategy for applying different active learning heuristic problem-solving approaches and methods to significantly improve students' attitude and performance. The active learning heuristic problem-solving approach is likely to support collaboration and discussions between teachers and amongst students themselves during the learning process. The findings show that most students from the experimental group worked collaboratively in their small groups and individually hence the conceptual and attitudinal change. The students helped and guided each other during peer teaching, hence boosting their attitude. As noted by Asempapa (2022), suitable teachers' instructional strategies that emphasize individual students' academic differences may change students' attitude towards LPMWPs, thereby providing both academic and social support.

Consequently, the low performers gained conceptual understanding, morale, and problem-solving strategies, hence positive attitude towards learning. This further enhanced students' learning and attitude towards mathematics and LP in particular. Besides, the active learning heuristic problem-solving approach applied to the experimental group boosted students' confidence in answering both routine and non-routine LP problems. Students' fear of comprehending LP word problems and attempting to answer LP questions decreased. Moreover, the heuristic problem-solving approach boosted students' attitude towards LPMWPs. Students were actively involved in problem-solving. This gradually built their motivation, competence, and confidence in learning LP and related concepts. This generally and significantly fostered students' positive attitude towards LPMWPs.

Limitations of the study and future research directions. The purpose of this research was to explore students' attitude towards LPMWPs. The findings provide preliminary insights into the fundamental concepts of the introduction of LP for supporting the learning of advanced mathematics. Our key observation is that the present study involved schools from two regions (Eastern Uganda and Central Uganda), and the study was specifically conducted in two districts (Mukono and Mbale). Yet, there are at least 120 districts in Uganda. Hence, the sample may not adequately represent all the 11th grade Ugandan students. Future studies should consider the inclusion of sampled students from all districts. While the quantitative study is important and valuable for yielding robust and comprehensive data in social sciences research, its limitations must be acknowledged. Triangulation of data collection and analysis methods might have yielded additional results. We, therefore, recommend future studies in different or similar settings and contexts, and in different mathematics topics (content) with a diversity of methods to compare and contrast our findings and to gain deeper and broader insights into students' attitude towards LPMWPs.

Students' attitudes point to issues related to demographic variables and latent constructs for learning mathematics. Specifically, to gain more insight, this research recommends that future researchers should use qualitative methods such as interviews and observation to provide more evidence on students' experiences in learning LP. The teachers 'attitude towards LPMWPs is also a potential area for further investigation aimed at improving the instructional strategies, pedagogical content knowledge, and mathematical knowledge for teaching. To achieve this, the teachers' professional development programs should be enacted to emphasize content knowledge and pedagogical content knowledge of learning LPMWPs. Teachers coming together to share learning experiences and strategies, may improve students' attitude towards learning LP, and other related but challenging topics. Indeed, teachers need continuous routine professional development support to successfully implement the learning activities. Despite some limitations, this study supplements other empirical shreds of evidence in support of enhancing students' attitude towards learning mathematics word problems, and LP in particular.

Data availability

All the data analyzed and reported in this study is available and may be accessed on request.

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Author contributions

RW: Conceptualization, design of suitable methodology, investigation, software, visualization, data analysis, and/or interpretation, preparation and writing of original draft, reviewing and revising it critically for important intellectual content, and final approval of the version to be published. VM and SB: Supervision, writing, reviewing, editing and final approval of the version to be published.

Competing interests

The authors declare no competing interests.

Ethical approval

Ethical clearance and approval were sought and granted by the Research and Ethics committee at the corresponding authors' university. Thus, all procedures involving human participants were respected and were streamlined following the ethical standards of the University's Directorate of research and ethics committee. Subsequent permission was sought and granted by the Ministry of Education and Sports, the district education officers, and finally the headteachers of sampled secondary schools.

Informed consent

All participants were informed and clearly explained to the purpose of the study. They were assured of confidentiality and, anonymity before they willingly signed the informed written consent form. The questionnaires were administered to the respondents during school working hours without interfering with the school-set timetable. Participants who opted not to participate in this research even after the distribution of questionnaires were allowed to withdraw. In addition, the consent form included the contact (s) of the principal researcher for further inquiries.

Additional information

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