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ISSN: (Print) (Online) Journal homepage: www.tandfonline.com/journals/rmse20

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To cite this article: Wajeah Daher & Faaiz Gierdien (18 Aug 2024): Use of Language By generative AI Tools in Mathematical Problem Solving: The Case of ChatGPT, African Journal of Research in Mathematics, Science and Technology Education, DOI: [10.1080/18117295.2024.2384676](https://doi.org/10.1080/18117295.2024.2384676)

To link to this article: <https://doi.org/10.1080/18117295.2024.2384676>



Published online: 18 Aug 2024.



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Use of Language By generative AI Tools in Mathematical Problem Solving: The Case of ChatGPT

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Texts generated by artificial intelligence agents have been suggested as tools supporting students' learning. The present research analyses the language of texts generated by ChatGPT when solving mathematical problems related to the quadratic equation. We use the functional grammar theoretical framework that includes three meta-functions: the ideational meta-function, the interpersonal meta-function and the textual meta-function. The results indicated that in at least one of six problem-solving tasks ChatGPT provided a mathematically incorrect answer. The processes appearing in ChatGPT texts, aiming at developing students' understanding of mathematical concepts, included verbal, mental, existential, relational and behavioural processes but no material processes. Specifically, ChatGPT performed a mathematically incorrect existential process. ChatGPT generally used the first plural pronoun 'we' when describing the processes of solving mathematical problems, while it generally used the first-person singular pronoun when taking responsibility for a specific mistake or when expressing happiness for the actions of the user. Moreover, generally the text of the solution did not include direct imperatives but used 'let us do'. The advancement of the ChatGPT textual solution was made usually through steps like 'first', 'second', etc. The research results indicated that the way ChatGPT responded to the mathematical problems would be useful in supporting learners' understanding of ways to solve quadratic equations, but only if the teacher critically accompanies the student in the problem-solving process. Self-study with ChatGPT could lead to or confirm students' mathematical misconceptions.

Keywords: Artificial intelligence; functional grammar; language processes; ChatGPT; mathematical word problems; quadratic equation

Introduction

Technology use has been widespread in the educational setting since its advent, and its use has been suggested for the advancement of students' learning in mathematics (Chinaka, 2021; Daher, 2020; Isaac & Childers, 2024; Stemele & Asvat, 2024). One technological tool that has attracted the attention of educational researchers in recent years is artificial intelligence (Tapalova & Zhiyenbayeva, 2022; Yilmaz & Yilmaz, 2023). One of the important generative artificial intelligence (AI) tools that has emerged recently is ChatGPT. As a tool for generating and assessing information, ChatGPT can play a variety of roles in teaching and learning, like collaboration coach, personal tutor or co-designer (Sabzalieva & Valentini, 2023). Educators have used ChatGPT for a variety of goals, to solve problems (Zhai, 2022) or to make students confident of their learning (Sánchez-Ruiz et al., 2023). One important feature of ChatGPT is its textuality, and thus the language that it uses in answering the learners' queries. In the present research, we analyse ChatGPT's use of language when solving mathematical word problems related to the quadratic equation. To do that, we use the

functional grammar theoretical framework developed by Halliday (1994) and suggested for analysing mathematical writing by Morgan (2005).

Artificial Intelligence in Education

According to UNESCO (2021), the concept of artificial intelligence refers to machines capable of imitating some human intelligence functions, including perception, learning, reasoning, problem solving, language interaction and even the accomplishment of creative work. Säuberlich and Nikolić (2018) argue that nearly all AI products require humans to insert content directly. They further argue that AI content could not be created without the assistance of linguists or phoneticians for natural language processing.

Previous studies indicate that AI positively influences students' learning outcomes from kindergarten to higher education contexts (Li et al., 2024). For example, AI positively influenced student achievement (Beslic et al., 2024), student motivation (Hmoud et al., 2024) and the attitude of students towards learning (Liao & Gu, 2022). In addition, AI has been successful in developing effective techniques for solving a wide range of problems in various disciplines (Xu et al., 2021).

According to Sabzalieva and Valentini (2023), ChatGPT is a language model that enables users to interact with a machine in a conversational manner. GPT stands for 'Generative Pre-trained Transformer', which represents a family of natural language models developed by Open Artificial Intelligence. Since it produces original outcomes, it is also called generative AI. In the ChatGPT context, artificial intelligence-based answers to questions and prompts are generated by analysing internet data, using natural language processing.

ChatGPT in Education

Since the emergence of ChatGPT on 30 November 2022, there has been a growing interest in using it in educational settings, to take advantage of its benefits. Qadir (2023) states that ChatGPT can respond swiftly and correctly to students' inquiries and questions. In addition, students can receive customised feedback and explanations on ChatGPT, as well as have the opportunity to engage in realistic virtual simulations for hands-on learning. Nevertheless, Qadir (2023) warns that using ChatGPT or other generative AI systems can perpetuate biases or even spread misinformation based on their training data. This implies that the human user of ChatGPT, additionally, needs to carefully check the ChatGPT responses. In addition, Limo et al. (2023) note that ChatGPT is capable of generating personalised practice problems for students, like generating practice problems tailored to their proficiency level, which would assist the teacher and the student, especially if the student has difficulty comprehending a particular mathematical concept. The teacher thus needs to think of the mathematical concept and its many representations and how these relate to the problem at hand.

Muñoz et al. (2023) found that students' motivation and engagement with second language learning were significantly and positively affected by working with ChatGPT. Moreover, learning interest and listening skills were significantly impacted by support by highly experienced instructors. Since the present generative AI tools may give incorrect responses, they require constant human intervention, so caution should be exercised before relying on ChatGPT.

Daher et al. (2023) found that ChatGPT faced difficulties related to conceptual knowledge across various conceptual categories, with more difficulties related to representations and depth, where these difficulties hindered effective knowledge transfer.

Functional Grammar

According to Halliday (1994), the English clause can be divided into three primary types of processes: material, mental and relational. Three subsidiary types at each boundary of the English clause are: behavioural (sharing characteristics of material and mental processes), verbal (sharing characteristics of mental and relational) and existential (sharing characteristics of relational and material).

Material processes are processes of doing and happening, while mental processes are processes of sensing (feels, thinks, wants, perceives, etc.). There are two types of relational processes: attributional, 'a is an attribute of x', and identifying, 'a is the identity of x'. Verbal processes are processes of saying that serve as a tool for creating narratives by opening up dialogic passages and include any exchange of symbolic meanings. The previous processes are part of the ideational function. An existential process represents something existing or happening, and it usually begins with 'be' or another verb expressing existence, like 'exist' or 'arise', followed by a nominal group being the existent.

The *ideational function* consists of the six processes and the resulting nature of mathematics (Morgan, 2005).

The *interpersonal function* addresses the relationship between the speaker/author and the hearer/reader. Through this function, the addresser imposes himself/herself into the context of the addressee. Doing that, the addresser wants to influence the attitudes and behaviour of the addressee (Halliday, 1994).

The *textual function* addresses the ways in which the message of the text is constructed. Thompson (1996) argues that textual meaning refers to the use of language to organise messages in a manner that indicates how they are related to each other and the broader context in which they are expressed.

Researchers have mainly used the functional grammar framework to analyse mathematical textbooks. For example, Daher and Abu Thabet (2020) studied the Palestinian mathematics textbooks for eighth grade using the functional grammar framework. Moreover, the framework was used to study the mathematical discourses. For example, Morgan (2005) used the framework to study the discourses of mathematics teaching and learning.

Moreover, Huang and Normandia (2007), through discourse analysis, reported the interrelationship between the construction of specific knowledge and specific lexical and grammatical features in mathematical writing. Alshwaikh and Morgan (2018) used texts from the teaching and learning of mathematics in Palestinian schools to sketch a picture of how mathematics is conceived in the Palestinian education system. They reported that a highly specialised discourse was found, emphasising the definition of formal objects and reasoning about their characteristics.

Daher and Abu Thabet (2020) found that the Palestinian Grade 8 mathematics textbook used a plural first-person pronoun to describe the need to engage with theorems, while it used the singular second-person pronoun to make the reader pay attention to specific properties of the mathematical objects. The textbook did not use any pronoun when coming to state the theorem. Furthermore, the textbook advanced mathematical reasoning as a narrative to make it easier for the reader. In addition, the mathematics textbook expected the learner to perform mainly relational and mental processes, and then material processes.

Research Rationale and Goals

The impact of AI on the student and the teacher in the mathematics and science classrooms is a topic of interest to educational researchers. They argue that there is need to educate students to cope with the impact of fundamental technological changes on society and the economy (Ogegbo & Ramnarain, 2022). Kanandjebo and Lampen (2022) say that when teachers use these tools, their existing beliefs and pedagogies are likely to be disrupted. Thus, research is needed to examine the possibilities and potentialities of AI in the mathematics and science classroom, which are themselves impacted by the language of AI tools, in our case by generative AI tools as ChatGPT. The present research intends to contribute to this issue.

Language and its use are one aspect of human behaviour, and so it is interesting to study how ChatGPT, as an AI tool, uses language in its solving of mathematical problems, here word problems related to the quadratic equation. The present research utilises the functional grammar framework (Halliday, 1994) to study the language that ChatGPT uses when solving word problems, which helps to explain both the method applied by ChatGPT to solve mathematical problems and its final solution of these problems.

It is not the goal of the present research to assess the correctness of the solving processes and solutions of ChatGPT, although we refer to this issue in the frame of describing the ideational function.

Research Questions

1. What are the characteristics of the ideational meta-function of ChatGPT's use of language when solving word problems related to the quadratic equation?
2. What are the characteristics of the interpersonal meta-function of ChatGPT's use of language when solving word problems related to the quadratic equation?
3. What are the characteristics of the textual meta-function of ChatGPT's use of language when solving word problems related to the quadratic equation?

Methodology

Research Context

We requested ChatGPT to solve six word problems related to the quadratic equation. The following problems were given to ChatGPT to solve, where we adopted the problems from Bajaj (2012) and Das (2023):

1. Building a community hall:
Suppose a builder decides to build a community hall of a building having a carpet area of 1000 square metres with its length 2 metres more than twice its breadth. What should be the length and breadth of the hall?
2. Area of the square:
If the measure of one side of a square is increased by 2 centimetres and the measure of the adjacent side is decreased by 2 centimetres, the area of the resulting rectangle is 32 square centimetres. Find the measure of one side of the square.
3. The path around the field:
A rectangular field is 16 metres long and 10 metres wide. There is a path of uniform width all around it, having an area of 120 square centimetres. Find the width of the path.
4. Arjun arrows:
The angry Arjun carried some arrows for fighting with Bheeshm. With half the arrows, he cut down the arrows thrown by Bheeshm on him and with six other arrows, he killed the rath driver of Bheeshm. With one arrow each, he knocked down respectively the rath, flag and the bow of Bheeshm. Finally, with one more than four times the square root of arrows he laid Bheeshm unconscious of an arrow bed. Find the total number of arrows Arjun had.
5. Reciprocals:
The sum of two numbers is 15. If the sum of their reciprocals is $\frac{3}{10}$, find the numbers.
6. The product:
The product of two consecutive even integers is equal to 24. Find these integers.

Data Collecting Tools

The first tool gave ChatGPT the six mathematical problems and requested it to solve these problems. The request was embedded in the text of the original problem (see the sixth problem above). Thus the prompts for such requests were: 'Find' or 'What should be'.

The second tool asked ChatGPT about specific points in the solution, where the points were related to the themes of the present research, such as the use of pronouns for example. Here, we used the prompts 'Why did you use ...'. For example: 'Why did you use the pronoun "we"? If we needed further

verification, we used the prompt 'elaborate'. For example: 'Can you elaborate on your use of the pronoun "we"?'

Data Analysis Tools

We used deductive content analysis to analyse ChatGPT's solutions of the six mathematical problems. In using the deductive content analysis, we used the functional grammar theoretical framework. Table 1 describes the themes for each meta-function.

We also performed inductive content analysis to find the values of each category related to each function of the functional grammar (ideational, interpersonal and textual). This enabled us to arrive at the incidences of each category. Thus we arrived for example at the incidences of the behavioural function, where one incidence of the satisfaction of this function was to write the goal of the problem and how to reach that goal.

Agreement Between Coders

We computed Cohen's kappa coefficient for the various categories related to functional grammar. We did that regarding the inductive content analysis. This computation resulted in values ranging from 0.88 to 0.92, indicating acceptable values for the agreement between coders. This ensured the reliability of the analysis process.

Results

Ideational Function

We will address the ideational function through addressing the processes performed by ChatGPT. Generally, ChatGPT performs verbal processes as the program is text-based. This nature of the program is acknowledged by the program itself, as in the following note when solving the 'The path around the field' problem:

I apologise for the confusion earlier. Since the problem involves a rectangular field with a path around it, a figure would indeed be helpful. However, I can't draw figures directly as a text-based AI. Instead, I will describe the figure to you.

Based on functional grammar, the processes involved in solving a mathematical problem by ChatGPT were of several types. Here, we considered verbs like 'solve', 'multiply' and 'simplify' as mental processes as the student who is engaged with them will arrive at the result of the process mentally. We will not report the material processes, as ChatGPT did not use such processes in its solution of the different problems. Below, we describe each one of the processes performed by ChatGPT.

Table 1. Themes and sub-themes considered during the deductive content analysis

The meta-function	Themes	Sub-themes
Ideational	Processes Nature of mathematics	Verbal, mental, material, behavioural, existential, relational Emergence of variables, reification, becoming
Interpersonal	Pronouns Verbs	First, second, third Singular, plural Imperative
Textual	Advancement of the text	Ways of writing the steps of the solution, ways of writing explanation sentences, ways of writing reasoning sentences

Existential Processes

These processes represent the occurrence or existence of something. They could come into existence by performing assumptions, 'letting be', etc.

Example 1: ChatGPT was given the 'Building a community hall' problem. It started the solution by writing: 'Let's assume the breadth of the hall to be " x " metres'. The assuming process is a type of existential process.

Another type of existential processes is the process of coming into existence by simplifying, rearranging, substituting or solving.

Example 2: ChatGPT was given the 'product' problem. ChatGPT wrote, towards the end of the solution, the following:

Set each factor equal to zero:

1. $n + 6 = 0 \quad n = -6$
2. $n - 4 = 0 \quad n = 4$

Here, ChatGPT simplified the algebraic expression and declared the emergence of the value of the variable by writing its value $n = -6$ or $n = 4$.

Sometimes the existential process was incorrect as Example 3 shows.

Example 3: ChatGPT was given the 'product' problem. ChatGPT wrote towards the end of the solution the following:

We have two potential solutions for ' n ', which correspond to the first even integer. However, since we're looking for consecutive even integers, the second solution ' $n = 4$ ' is the one we need.

Above, ChatGPT answered that the second solution is the one we need, while the first is disqualified. Therefore, ChatGPT gave an incorrect solution for the quadratic word problem, as $n = -6$ could also result in a solution. Thus, a critical mathematics teacher is needed in the work of students with AI tools. It seems that these tools have considerable risks as learning tools when only manipulated by the student.

Verbal Processes

Verbal processes were concerned with the goal of the action. At the beginning of the solution, ChatGPT might write the goal of the problem and how to reach that goal. This happened in the solution of the 'Arjun arrows' problem: 'Let's break down the information given step by step to find the total number of arrows Arjun had'. The previous process 'Let's break down' is a general process that would fit the solution of other word problems, where the goal changes according to the content of the word problem.

Mental Processes

ChatGPT details the mental processes that are part of the solution, like simplifying, rearranging, substituting, solving, etc.

Example 1: Using 'simplifying' and 'rearranging' in the solution of 'Building a community hall' problem.

Simplifying this equation, we get:

$$1000 = 2x^2 + 2x$$

Rearranging the terms, we get a quadratic equation:

$$2x^2 + 2x - 1000 = 0$$

Alternative Mental Processes

ChatGPT sometimes seems concerned with the alternative mathematical solving methods that could be used in performing a mathematical step. For example, ChatGPT wrote in the solution of the 'Arjun arrows' problem:

We can solve this equation by factoring, completing the square, or using the quadratic formula. In this case, let's use the quadratic formula.

Relational Processes

These processes involve attributional processes.

Example 1: solving the 'Area of the square problem', ChatGPT described how the lengths of the sides of the square change as a result of the change in their properties: 'When one side of the square is increased by 2 centimetres, the length of the resulting rectangle becomes $x + 2$ '. The second part of the sentence involves a relational process as it describes the becoming attribution of the square's side.

Relational processes in ChatGPT solution texts also come as justification processes using the adjunct 'when' or 'since', for example using 'when' in the solution of 'Area of the square' problem in the quote above.

The sentence that comes after 'when' is an explanation of the subsequent sentence and thus it includes a relational process.

Example 2: Using 'since', as in the solution of 'Area of the square' problem.

Being concerned with reasoning, ChatGPT used logical connectors like 'since' in the 'Building a community' hall problem: 'Since the breadth of the hall cannot be negative, we can discard the negative solution'.

Behavioural Processes

ChatGPT used few behavioural processes.

Example 1: Using 'set up' and 'look for' in the solution of the 'product problem'—'We can set up the equation' and 'You are looking for two consecutive even integers'.

We can summarise that ChatGPT used mainly mental processes, existential processes and relational processes. It used the verbal text to describe relational processes, besides algebraic processes.

Nature of Mathematics

The nature of mathematics that arises from the solution texts by ChatGPT is that mathematics can be learned when an expert (ChatGPT) accompanies the learner in the solution process. In addition, the nature of mathematics that emerges from solution texts is the need for multiple processes (mental, existential, relational, behavioural) that help the learner construct the solution of the mathematical problems. In addition, mathematics is a multiple-aspects entity, where it consists of setting goals, making assumptions, being aware of mathematical relationships, emphasising the mathematical processes and being aware of the different solution processes of a mathematical problem.

Interpersonal Function

The interpersonal function included the use of pronouns and the use of the imperative verb.

Using the first-person plural pronoun

ChatGPT generally used the first-person plural pronoun when describing the processes it wanted to perform as part of the solution, or when describing the problem-solving strategy, as in the solution of the 'path around the field' problem: 'To find the width of the path, we need to subtract the area of the rectangular field from the total area including the path'.

When asked ChatGPT clarified that it referred to 'we' as a linguistic convention simply to include both the problem solver (the requester of the solution) and itself in the thought process. ChatGPT

continued: 'In reality, I am here to assist you as the problem solver, providing explanations, guidance, and solutions to the best of my abilities'.

Using the first-person singular pronoun

ChatGPT generally used the first-person singular pronoun when taking responsibility for a specific mistake, as when it discussed the length of the solution as for the 'path around the field' problem: 'I apologise for the lengthy solution'. Another incidence of using the first-person singular pronoun was when ChatGPT expressed happiness for the actions of the user, as in the same discussion above: 'I'm glad to hear that you found a shorter way to solve the problem'.

When asking ChatGPT when it uses the the first-person singular pronoun, it answered: 'The use of "I" helps to establish my identity as the AI model and differentiate my responses from those of the user or other entities involved in the conversation'.

Using the second-person singular pronoun

One incidence of ChatGPT's use of the second-person singular pronoun was when ChatGPT appreciated the user's patience, or when the generative AI told the user that it would assist her/him when necessary. This occurred for example when solving the 'path around the field' problem: 'I appreciate your patience, and I'm here to assist you with any further questions or problems you may have'. Another incidence occurred when ChatGPT gave the user credit upon providing a shorter solution method (see the quote in the previous paragraph).

Imperatives

Generally, the text of the solution did not include direct imperatives. ChatGPT used the indirect imperative 'let's do' as in 'let's solve this equation to find the value of x, which represents the total number of arrows Arjun had' in the solution of 'Arjun arrows' problem. It also used the indicative declarative form 'We can do' as in 'We can solve this equation by factoring'. In addition, it used the future indicative declarative form 'we will do' as in 'we'll need to use numerical methods or approximation techniques'.

Summarising the interpersonal function, ChatGPT used mainly the indirect imperative, but it also used the present simple tense with and without a modal verb like 'can'. In addition, ChatGPT used usually the plural first-person pronoun 'we', but sometimes used the singular or plural second-person pronoun.

Textual Function

The textual function included ways of writing the steps of the solution, ways of writing explanation sentences, ways of writing reasoning sentences and ways of specifying equations.

Ways of writing the steps of the solution

ChatGPT used the following expressions when writing the steps of the solution: 1., 2., 3., etc. or first, next, now, then, also, etc.

Example 1: ChatGPT used 'now' in the solution of the 'Building a community hall': 'Now, we know that the area of the hall is 1000 square metres. We can use this information to write an equation as follows'.

Example 2: ChatGPT used 'Also' in the 'Reciprocals' problem: 'Also, we know that the sum of their reciprocals is 3/10. Therefore, we can write another equation as:

$$1/x + 1/y = 3/10 \text{---(2)'}$$

Ways of writing reasoning sentences

ChatGPT used logical connectors, as 'Since ... , we need ... ', 'which is ... ', 'Therefore ... ', 'So, ... ' or 'according to ... '. In addition, ChatGPT sometimes wrote the reasoning before the conclusion.

Example 1: ChatGPT used the logical connector ‘Since ... , we need ...’ in solving the ‘Path problem’: ‘Since the area of the path is given in square centimetres, we need to convert it to square metres’.

Example 2: ChatGPT wrote the reasoning before the conclusion in solving the ‘Arjun arrows’ problem:

According to the given information, the remaining number of arrows after all these steps should be enough to lay Bheeshm unconscious. Therefore, we can set up the following equation.

Above, the clause ‘According to ...’ is the explanation for the clause ‘the remaining ...’, and the second clause is the explanation of the sentence ‘Therefore ...’.

Ways of specifying equations

ChatGPT usually arranged equations using numbers as in the ‘Reciprocals’ problem (see the equation above, where ChatGPT numbered it ‘2’, as it came after an equation that ChatGPT numbered as ‘1’).

Summarising the textual function, ChatGPT used logical connectors such as ‘since’ and ‘so’, and time connectors such as ‘now’. In addition, ChatGPT advanced through transiting from a mathematical behavioural process to an existential process or relational process. Sometimes, the advancement happened in reverse, i.e. from an existential process or relational process to a mental process.

Discussion

In the present research, we utilised the functional grammar theoretical framework to study the meta-functions of language used by ChatGPT to solve mathematical problems related to the quadratic equation. The research results indicated that ChatGPT frequently used verbal, mental, relational and existential processes, occasionally behavioural processes and no material processes. Analysing the Palestinian mathematics book, Daher and Abu Thabet (2020) reported that relational and mental processes occurred frequently, while material processes occurred occasionally. Moreover, they reported that few behavioural and verbal processes occurred, while existential processes did not occur. So, the similarity between the two studies is in the frequent occurrence of mental and relational processes and the limited occurrence of behavioural processes, while the difference is in the occurrence of the other processes. The similarity between the textbook and ChatGPT studies shows the importance of relational processes in mathematics problem solving (Tong et al., 2023). Equally, mental processes are acknowledged as central to the nature of mathematical reasoning (Morgan, 2005), whereas behavioural processes are more akin to reasoning in the sciences (Chinaka, 2021).

ChatGPT was concerned with existential processes through assuming that a given in the mathematical problem was an unknown. The assuming process was a type of identifying process leading to the emergence of a variable, which emphasises the process–object duality (Sfard & Linchevski, 1994). This duality states that the factors and products as objects, found in quadratic equations, are simultaneously computational processes.

In addition, ChatGPT performed at least one incorrect existential process in solving the quadratic problems in the present research. This happened in solving the product problem when it concluded that $n=4$ was the only solution of the problem. The potential for incorrectness in problem solving has also been reported by previous studies (Daher et al., 2023; Qadir, 2023). So, working with generative AI tools in mathematics classrooms is therefore not a self-study activity. The teacher should be present to direct the students’ problem-solving in this type of activity (Säuberlich & Nikolić, 2018). Whenever such incorrectness occurs, the teacher can intervene to discuss it with the students. This underlines the point that an experienced and critical mathematics teacher is needed when arranging activities based on AI-based tools (NCTM, 2024).

In addition, these situations of incorrectness in the ideational processes could be utilised in the mathematics classroom to facilitate mathematical understanding and specifically word problem-

solving ability. The teacher can request the students to ask ChatGPT to solve a mathematical problem and then request the students to decide the correctness of each ideational process the tool performed. This would make learning with generative AI tools more student centred (Muñoz et al., 2023), as compared with ChatGPT solving problems in accordance with the students' request emerging from the teacher's task. This role of the teacher does not encourage active participation of the students. Therefore, utilising situations of incorrectness of the generative AI tool contributes to student centredness in the mathematics classroom, because students will have to check whether the computational processes and answers are correct. In addition, letting students work in groups and requesting them to discuss the ideational processes of the generative AI tool would make this learning more student centred (Overby, 2011), in terms of the problem-solving steps and processes.

The relational processes involve attributional processes. One instance of these processes is the becoming process. In addition, the relational processes came to justify a becoming process or a choosing process by using the adjunct 'when' or 'since'. The nature of mathematics reflected in the processes was that of the emergence of variables, reification, that is, the emergence of mathematical objects. Thus, ChatGPT took care of justifying the mathematical processes taken by it, showing awareness of the need to do so. This indicates that mathematical justification is used for improving students' understanding of mathematics and as showing their competence in doing mathematical actions (Staples et al., 2012; Valero, 2014).

The mental processes involved mathematical processes that occurred as part of the solution, like simplifying, rearranging, substituting, solving, etc. Moreover, ChatGPT sometimes pointed out alternative methods that could solve the mathematical problem. This concern with alternative mental processes could be considered as a concern with creativity, where the different methods point at the concern of ChatGPT, as a supporter of learners, with flexibility, a process pointed at as needed in the mathematics classroom (Daher & Anabousy, 2018). Another possible explanation is that ChatGPT wanted to show its ability as a learner, indicating that the generative AI environments could help show this learner's ability, and thus encourage this learner's ability when human learners work in these environments.

In solving the problems related to the quadratic equation, ChatGPT did not use the material processes, which is expected, as ChatGPT knowledge depends on the information on the internet. This means that it does not engage in material processes in order to arrive at the knowledge related to the quadratic equation.

ChatGPT generally used the first plural pronoun 'we' when describing the processes of solving the mathematical problems. What does this use indicate? Asking ChatGPT about this use, it talked about itself as supporter of the learner and not a problem solver. This is in line with Wardat et al. (2023), who argued that ChatGPT provides feedback and assistance for students in their learning of mathematics. The claim of ChatGPT could also reflect researchers' consideration of ChatGPT as empowering learners (e.g. Gašević et al., 2023).

Moreover, ChatGPT generally used the first-person singular pronoun when taking responsibility for a specific mistake or when expressing happiness about the actions of the user. When asking ChatGPT when it uses the the first-person singular pronoun, it answered that this use helps to establish its identity. Thus, ChatGPT considers the use of 'I' as a means of differentiation from the user. Williams (2012) found that English first-person verbs frequently serve to promote oneself. Here, the use of 'I' in ChatGPT solutions could indicate taking responsibility, while the answer of ChatGPT regarding this use mentions also the promotion of oneself.

Generally, the text of the solution does not include direct imperatives, whereas Dawoud and Daher (2022) reported that the direct imperative was prominent in algebra sections in some mathematics textbooks. Instead, ChatGPT used the indirect imperative 'let's do', the indicative declarative form 'We can do' and the future indicative declarative form 'we will do'. These indirect imperatives indicate the inclusion of the speaker in the process. Thus, the imperatives are not directed to the reader only, but also to the author, which indicates closeness of the relationship between ChatGPT and the user.

ChatGPT, when writing the solution of a mathematical problem, showed the solution steps through different means such as 1, 2, 3, etc. or first, next, now, then, also, etc. This in line with the mathematics

textbook that uses conjunctive time adverbs – specifically the successive one (using 'next', 'first', 'second' and 'third') to indicate the advancement of the processes in the mathematical text (Daher & Abu Thabet, 2020).

ChatGPT used numbers to indicate equations and was concerned with explaining these steps and justifying them. These means of taking care of the textual solution indicate that ChatGPT was aware of the need for mathematical writing, explanation and justification in the mathematical problem solving (Hershkowitz et al., 2017; Urquhart, 2009). Moreover, the occurrence of these relational processes (explanation and justification) could be highlighted by teachers as opportunities for learners to develop mathematical understanding, since explanations are more likely to support the development of learners' word problem-solving ability than more expository processes.

Conclusions

In the present research, we studied the language that ChatGPT used when solving mathematical problems related to the quadratic equation. To do so, we utilised the functional grammar theoretical framework that includes three meta-functions: the ideational, the interpersonal and the textual. The research results indicate that ChatGPT could give incorrect ideational processes. Earlier research has pointed to these situations of incorrectness, recommending that since AI tools may give incorrect responses, they require constant human intervention, which should be taken into consideration before they are relied upon as generative tools.

The conclusion here is that the teacher should take these incidences into account when designing classroom activities with generative AI tools. It is concluded that ChatGPT is inappropriate for student self-study as it may give incorrect answers in the problem-solving process. It could be used in the presence of the teacher. Another option is making the ChatGPT-based mathematical activities collaborative, which can support students in tackling these mistakes, in addition to encouraging the interaction between students and the generative AI tool.

The analysis of the interpersonal function showed that ChatGPT considered itself part of a learning community, so it generally used the first-person plural pronoun. Future research should investigate this perception of the generative AI tool, especially when it considers itself as a member of a learning community.

The analysis of the textual function indicated that ChatGPT was aware of the importance of mathematical writing, i.e. that it is not enough to solve a mathematical problem using variables and equations, and that the solution should include verbal texts that have many functions, as for example, describing the solution process, describing the mathematical process and describing the explanation for the actions performed.

In the present research, we analysed ChatGPT's texts considering it a learner, where it seems that ChatGPT considers itself a supporter of the learning process. So, future research could study the language of generative AI as a supporting companion of the learner.

Moreover, in the present research, we did not consider the language of ChatGPT in its interaction with the user, as when the user asks it questions like 'Why did you do this or that?', 'What do you think about this or that?', or 'Can you provide another solution of the same problem?', making the learning more student centred. Future research is needed to study ChatGPT language in this case.

In addition to the above, the present research did not address the issue of ChatGPT's language use in the multilingual mathematics classroom. Future research is needed to study the suitability of the use of the English language by ChatGPT in supporting the development of word problem solution strategies in multilingual mathematics classrooms.

Disclosure Statement

No potential conflict of interest was reported by the author(s).

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Appendix.

Appendix 1: Analysis of ChatGPT's Solution of the Product Problem

The Problem

The product of two consecutive even integers is equal to 24. Find these integers.

The solution sentences	Functional grammar analysis
Let's solve this problem.	Id: A mathematical behavioural process (solve). Int: Indirect imperative verb (Let's). The pronoun used is the plural first-person pronoun.
You are looking for two consecutive even integers, and their product is equal to 24.	Id: A behavioural process (look for). Int: The pronoun used is the singular/plural second-person pronoun (we).
We can represent these integers as ' n ' and ' $n + 2$,' where ' n ' is the first even integer, and ' $n + 2$ ' is the next consecutive even integer.	Id: Existential process (represent these integers). Int: The pronoun used is the plural first-person pronoun (we).
According to the problem, the product of these two integers is 24.	A relational process (stating a verbal equation). This relational process/ is at the same time an explanation process. Int: the values of the interpersonal function are absent.
So, we can set up the equation: $n \times (n + 2) = 24$	A behavioural process (can set up), and a relational process (stating an algebraic equation) that is a conclusion. Int: There is no imperative in the statement. The pronoun used is the plural first-person pronoun (we).
Now, let's solve this equation: $n^2 + 2n = 24$	Id: A behavioural process (solve). Int: Indirect imperative verb (Let's). The pronoun used is the plural first-person pronoun.
To simplify further: $n^2 + 2n - 24 = 0$ Now, we can factor the quadratic equation: $(n + 6)(n - 4) = 0$	Id: two mental processes (simplify, factor) and a relational process (concluding an algebraic equation). Int: There is no imperative in the statement. The pronoun used is the plural first-person pronoun (we).
Set each factor equal to zero: 1. $n + 6 = 0$ $n = -6$ 2. $n - 4 = 0$ $n = 4$	Id: A relational process (setting algebraic equations). Int: an imperative verb (Set). The pronoun used is the singular second-person pronoun.
We have two potential solutions for ' n ', which correspond to the first even integer. However, since we're looking for consecutive even integers, the second solution ' $n = 4$ ' is the one we need.	Id: An existential process (the existence of solutions), a relational process of the type 'explanation', and another existential process (the existence of a solution). Int: There is no imperative in the statement. The pronoun used is the plural first-person pronoun (we).
The next even integer is ' $n + 2$ ': $n + 2 = 4 + 2 = 6$	Id: An existential process (the existence of another solution). Int: the values of the interpersonal function are absent.
So, the two consecutive even integers whose product is equal to 24 are 4 and 6.	Id: An existential process (the existence of two solutions). Int: the values of the interpersonal function are absent.

The textual function of ChatGPT solution of the product problem appears to include logical connectors as 'since' and 'so', and time connectors as 'now'. In addition, the mathematical text advances from the situation description to the mathematical relations that arise from the situation. Specifically, it advances from the mathematical behavioural process to an existential process or a relational process. In addition, all the imperative verbs are indirect, using the formulation 'Let us'.