



# Prof Pi: Using Whatsapp Bots and GPT-4 for Tutoring Mathematics in Underserved Areas

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**Abstract.** Mathematics education is often a prerequisite for studying certain subjects further at tertiary institutions. Mathematics education is a type of gate keeper for further education. In underserved areas, pupils often need more help with mathematics than it is possible to provide. This could be due to financial reasons (lack of budget in the education system), geographical reasons (pupils living in extremely rural areas), or temporary health restrictions (as seen during the COVID lockdowns when schools were closed in many countries). Prior research by the authors showed that *Prof Pi*, a Whatsapp Bot linked to OpenAI's GPT-4 large language model, could tutor mathematics at university level in the Arabic language. While that prior educational research was being conducted, violent unrest rocked the area where the university was located and many people started to leave the area. Sad as this was, it provided an opportunity for the researchers to observe *Prof Pi* operating in an underserved area.

**Keywords:** Whatsapp · bots · GPT-4 · tutoring · mathematics

## 1 Introduction

In January each year, the South African Department of Basic Education releases the results of the end of year examinations for the previous academic year for secondary schools. Technically, the examinations are called the *National Senior Certificate* but colloquially they are known as the *matric*. Pupils who had finished Grade 12 just before the Christmas break had spent a nervous holiday season worrying about their *matric* results.

In many ways, however, the various adults involved in education in South Africa such as parents, teachers, school administrators, government officials, and politicians worry about the results of the examinations just as much as the pupils themselves.

With respect to this paper, the examination subject of most interest is the mathematics examination results. South Africa offers two different mathematics examinations for the Grade 12 pupils: Mathematics and Mathematical Literacy. A good result on the Mathematics examination (also called Technical Mathematics) is a pre-requirement to studying more technical subjects at a tertiary level such as physics and computer science.

According to the report issued by the Department of Basic Education, a total of 725,146 pupils wrote the examinations at the end of the 2022 academic year. Of those 725,146 pupils, 269,734 wrote the Mathematics examination. And of those 269,734 pupils, only 148,346 (55%) passed the examination with at least a 30% pass mark. This was, sadly, a decrease from the previous year [1].

One could argue that the calculation of the percentage of pupils who passed (55%) should be calculated as a percentage of all of the pupils who wrote the exams and not just the number of pupils who wrote the Mathematics exams. Others prefer to argue that the calculation of the percentage of pupils who passed should be calculated as a percentage of all the pupils who started school back at Grade 0 or Grade 1 twelve or thirteen years prior to this examination. This paper does not touch those arguments.

This paper is not to bemoan the results of these examinations. It is to ask the question of whether or not there are innovative multi-disciplinary ways to help with mathematics education – especially in underserved areas.

Specifically this paper looks at how advances in social media platforms merged with recent advances in language modeling can be used in helping pupils who might need extra tutoring but live in underserved areas where tutors are not available.

This paper describes an artifact called *Prof Pi* which can be used to tutor mathematics in areas where human tutors are not available. These underserved areas could be caused by economic reasons such as lack of finances to pay tutors, physical reasons such as rural areas, or temporary health measures such as happened in 2019 and 2020 during the hard lockdowns imposed by politicians around the world due to the COVID outbreaks.

Section 2 of this paper provides a literature review and specifically looks at prior research done by the authors in mathematics tutoring. Section 3 describes a number of issues or challenges with face-to-face tutoring situations where tutors and pupils meet in-real-life. Section 4 discusses the ethical issues surround this specific project. Section 5 describes the research methodology used for producing this prototype. Section 6 provides a description of the prototype and its components. Section 6 also provides sample dialogs which could happen between a pupil and *Prof Pi*. During the period of time this paper was being written, unrest broke out in Khartoum, Sudan, and *Prof Pi* was deployed to assist university level students with their mathematics problems using Arabic language. Information on that can be found in Sect. 7. Concluding remarks and future work is found in Sect. 8.

## 2 Previous Research in Distance Education and Remote Tutoring

Remote tutoring is a subset of distance education. Distance education has a very long and rich history. One could actually even argue that distance education is documented in Biblical times referring to Paul's letters to the distant churches.

Rolling through time quickly, however, postal courses in the United States [2] and Britain [3] sent printed materials to students. These students were often in underserved areas where they could not attend face-to-face courses. Radio courses and television courses emerged in the first half of the twentieth century again often targeting students in underserved areas.

These three modes of communication, however, postal, radio, and television, were mostly uni-directional: information was sent from the teacher or tutor to the student or

pupil. As the Internet matured, lessons could become bi-directional allowing the student and pupil to actively take part in these remote lessons.

In the underserved world (also often called the *developing world*), the use of cell phones enabled pupils and students to reach chat rooms and mobile websites to assist with their education.

The authors have previously worked on a mathematics tutoring project using text based chat systems. That project, *Dr Math*, is well reported in the literature [4, 5]. Dr Math linked human tutors to pupils using internet technologies. Extensive work was done to handle the potential problems documented in Sub-Sect. 3.2 following.

### 3 Issues with Face-to-Face Tutoring and Remote Tutoring

There are a number of issues present in face-to-face tutoring and remote tutoring which need to be discussed.

For the scope of this section, the expression *face-to-face tutoring* refers to when a tutor and a pupil meet physically in order to discuss their academic issues. These issues will be discussed in Sub-Sect. 3.1. The expression *remote tutoring* refers to a situation where a real human tutor and a real human pupil communicate using internet technologies such as tele-conferencing or text chat facilities. These issues are discussed in Sub-Sect. 3.2.

#### 3.1 Issues with Face-to-Face Tutoring

In any situation where children meet up with adults, care must be taken to protect the children from any harm perpetrated by the adult. And, care must be taken to protect the adult from any harm to the adult caused by false allegations by a child. Both of these are difficult challenges.

Perhaps the easiest to target is protecting the children from the adult. This is often facilitated by requiring police checks of the adults ensuring they do not have a history of harming children. Other strategies include having unannounced visits by supervisors to check in on the interactions between the adults and children.

Protecting the adult from false allegations by a child is more problematic but the risk can be mitigated by having rules in place which never allow an adult and child alone together in an enclosed area and to always ensure that there are more than one adult and more than one child at each interaction.

In underserved areas, however, many of the attempts to protect the participants are expensive in manpower and can not actually be implemented because of lack of such manpower.

#### 3.2 Issues with Remote Tutoring

In the situation of remote tutoring, there are also a number of concerns. Three of these concerns include 1) the remote tutoring platform being used to exchange unacceptable photographs or conversation (such as pornographic images) 2) the remote tutoring platform being used to facilitate face-to-face meetings between the participants and 3) the remote tutoring platform being used to facilitate the sale of illicit items such as drugs.

There are a number of ways to mitigate these problems depending on whether the remote tutoring is working over chat facilities or tele-conferencing facilities. But both require some sort of keyword recognition and human monitoring.

In the case of underserved areas, both of these can be hard and expensive to implement in terms of manpower.

## 4 Ethics

This project was to evaluate *Prof Pi*, a Whatsapp Bot linked to the GPT-4 API configured to act as a mathematics tutor, and determine if it was suitable for use in underserved areas. For the scope of this paper, *Prof Pi* was never presented to actual pupils. No minor children or any human subjects were used for the scope of this paper. As such, no ethics approval for this research paper was required. Prior educational research with *Prof Pi* in an underserved area during times of violent unrest which is discussed in Sect. 7 did have an ethics approval by the university involved.

Having said that, the Dr Math project mentioned above in Sect. 2 did have an ethics approval. In many of the publications about Dr Math, conversations were published in papers and in data bundles. Many of those conversations were used as test data in this *Prof Pi* project.

## 5 Research Methodology

At the beginning of the original development of the *Prof Pi* artifact, it was not known whether or not it would be possible to configure GPT-4 and Whatsapp to work together to provide tutoring services in mathematics. Because of this, Design Science Research methodology was used to guide this project.

Design Science Research is an iterative approach to solving real world problems. Design Science Research involves three inter-woven cycles: 1) A relevance cycle which ensures that a real world problem is being tackled 2) A rigor cycle which ensures that scientific rigor is used in attempting to solve this real world problem and 3) a design cycle which binds everything together [6]. Hevner illustrates these three inter-woven cycles as in Fig. 1.

In attempting to solve a real world problem, followers of Design Science Research must create artifacts. These artifacts embody new knowledge. There are a number of types of artifacts which can be created by Design Science Research. These include constructs, models, frameworks, architectures, design principles, methods, and instantiations [7].

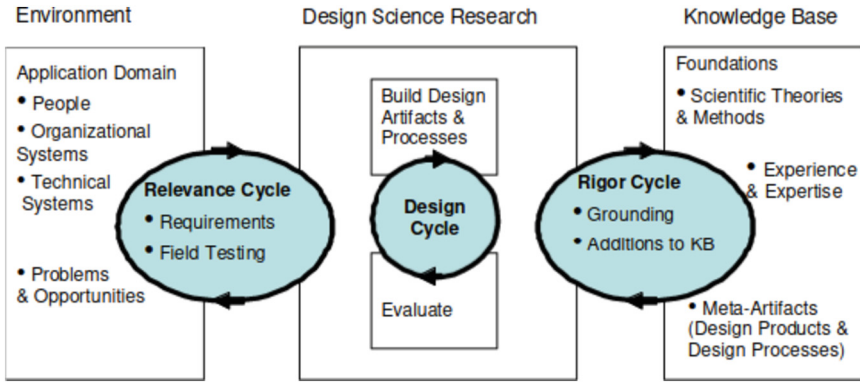


Fig. 1. The three cycles of Design Science Research

### 6 Prof Pi Description

*Prof Pi* is a Whatsapp bot designed to assist students with their mathematics homework using GPT-4. It offers a powerful and accessible solution for learners seeking guidance and support. This bot operates within the popular messaging platform, Whatsapp, allowing students to interact with it in a familiar environment. By leveraging GPT-4’s advanced natural language understanding and generation capabilities, the bot can comprehend and respond to a wide range of mathematical inquiries, ranging from basic arithmetic to more complex concepts. This intuitive interaction makes the learning experience engaging, effective, and enjoyable for students, while also providing instantaneous feedback and personalised assistance.

The integration of GPT-4 into a Whatsapp bot for mathematics tutoring is particularly beneficial and cool because it merges the advanced capabilities of a state-of-the-art AI model with the convenience of a widely-used messaging platform. Students can easily access the bot on their devices, making it an ideal tool for remote learning or on-the-go support. Furthermore, GPT-4’s proficiency in natural language processing allows the bot to understand and respond to complex mathematical problems in a conversational manner, simulating the experience of interacting with a human tutor. This innovative approach to math tutoring has the potential to transform the way students learn and engage with mathematical concepts, making education more accessible, significantly more inexpensive and enjoyable for learners of all levels.

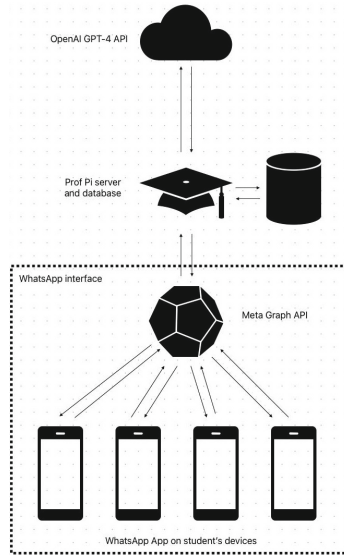
One of the most important features of *Prof Pi* is that it is configured to be a Socratic tutor and it does not just provide students with the exact answers to the questions. *Prof Pi* engages the student in dialog so that the student solves his own question and, thereby, learns something. If students just want answers, they can access the GPT-4 API directly using OpenAI’s chatGPT website. *Prof Pi*, on the other hand, is a tutor to guide the students into solving their own problems.

Sub-Sect. 6.1 describes the overall architecture of the artifact. Sub-Sect. 6.2 provides a brief description of how Whatsapp bots actually work. Sub-Sect. 6.3 provides a description of GPT-4 and some of the configuration problems which needed to be solved.

Sub-Sect. 6.4 provides some sample chat dialogs with the authors to demonstrate how *Prof Pi* works.

## 6.1 Overall Architecture

The architecture of the system for assisting students with their mathematics homework can be broadly divided into three main components: the Whatsapp interface, the backend server, and the GPT-4 API integration. This can be seen in Fig. 2.



**Fig. 2.** Prof Pi Architecture

The Whatsapp interface facilitates user interactions, allowing students to communicate with the bot using natural language or mathematical notation. The backend server processes incoming messages, manages user sessions, and orchestrates the communication between the Whatsapp/Meta platform and the GPT-4 API. Lastly, the GPT-4 API integration enables the bot to access the powerful natural language understanding and generation capabilities of the GPT-4 model, allowing it to generate meaningful and contextually relevant responses to students' inquiries.

When a student sends a message or question to the Whatsapp bot, the Whatsapp/Meta platform forwards the message to the *Prof Pi* backend server. The server then processes the message and prepares it for submission to the GPT-4 API. This may involve tokenisation, formatting, or incorporating relevant context from previous interactions. Once the message is processed, the server sends a request to the GPT-4 API, which generates an appropriate response based on its understanding of the context and the mathematical query. The *Prof Pi* backend server receives the response from the GPT-4 API, processes it if necessary, and sends it back to the student via the Whatsapp platform.

The platform is built in such a way that the identity of the student is never received nor stored on the server. The only identifying information is a cell number of the student. The bot is also programmed to filter and delete all attempts to provide personal information. This protects the identities of the students.

## 6.2 Whatsapp Bots Description

Whatsapp bots are specialised software applications that run within the Whatsapp/Meta messaging platform, automating tasks and providing a wide range of services to users. Bots can interact with users through commands, text, images, and other media, enabling them to perform actions such as sending notifications, managing groups, retrieving information, or facilitating communication. In recent years, Whatsapp bots have gained popularity due to their versatility, ease of use, and the convenience they offer to both developers and end-users.

The functionality of a Whatsapp bot is based on its ability to receive and process user inputs in the form of messages or commands. When a user interacts with a bot, the Whatsapp/Meta server forwards the relevant information to the bot's designated web-hook URL or retrieves it via long polling. The bot's response can then be sent back to the user via Whatsapp, which facilitates seamless communication within the platform.

Whatsapp bots have emerged as powerful and adaptable tools without the need for downloading apps. Their low data consumption and minimal hardware requirements make them particularly valuable in underserved areas where access to resources may be limited. By automating routine tasks, providing instant access to information, and facilitating communication, these virtual assistants can greatly improve the user experience for students, educators, and researchers. As the technology continues to evolve, it is likely that the range of applications for Whatsapp bots will only expand, offering increasingly innovative solutions to address the ever-changing needs of the educational landscape. With the integration of artificial intelligence and machine learning, Whatsapp bots hold the potential to revolutionise the way we approach teaching, learning, and research.

## 6.3 GPT-4 Description

GPT-4, or Generative Pre-trained Transformer 4, is an advanced multi-modal language model developed by OpenAI, which has garnered significant attention due to its remarkable natural language understanding and generation capabilities [8]. Built on the transformer architecture, GPT-4 is pre-trained on a massive corpus of text data, enabling it to generate contextually relevant and coherent responses to a wide range of language-related tasks. With 175 billion parameters, GPT-4 has demonstrated a high level of proficiency in various applications, such as machine translation, summarisation, question-answering, and even tasks that require logical reasoning.

The underlying strength of GPT-4 lies in its self-attention mechanism and unsupervised learning approach, which allow the model to capture complex patterns and relationships within the input data. During the pre-training phase, GPT-4 learns to predict the next word in a sentence based on the context provided by previous words, resulting in a robust understanding of syntax, semantics, and even nuanced language constructs. This

extensive knowledge base enables GPT-4 to generate contextually appropriate responses when prompted with user-generated text or questions, making it a versatile tool for various applications.

In the context of mathematics mentoring, GPT-4's ability to understand and generate natural language makes it a promising candidate for providing guidance, explanations, and problem-solving assistance to students. Its proficiency in recognising and processing mathematical notation, coupled with its capacity for logical reasoning, allows GPT-4 to address a diverse range of mathematical topics, spanning from basic arithmetic to advanced concepts. Moreover, its capacity to generate human-like responses enables GPT-4 to engage with students in a more interactive and intuitive manner, potentially fostering a more effective and engaging learning experience.

## 6.4 Sample Dialogs

This section provides some examples of how the prototype could operate in a tutoring environment for mathematics. The conversations are presented as text taken from the log files. To save space, they are not presented as images from the cell phone screen. There are five examples with one example each in algebra, geometry, trigonometry, calculus, and a story problem.

In the following sample algebra question, the pupil converses with *Prof Pi* as if *Prof Pi* were a human being using expressions such as “umm”, and “oh right, my bad.”

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Student: hey, i need help with this question, its asking me to solve  $2x - 6 = 10$ ?
Prof Pi: Hi there! Sure, I can help. First, can you try isolating the term with the
variable (x) by performing the same operation on both sides of the equation?
Student: ok so i add 6 to both sides, i get  $2x = 16$ 
Prof Pi: Great job! Now, what should you do next to find the value of x?
Student: umm i think i should add 2 to both sides
Prof Pi: Almost! Remember, we want to isolate x by itself. Which operation
should you use to do that?
Student: oh right, my bad, i should divide both sides by 2
Prof Pi: That's correct! Go ahead and divide both sides by 2 to find the value of
x.
Student: cool, so  $x = 8$ 
Prof Pi: Well done! You've found the correct value for x. Keep practicing, and
you'll continue to improve!
```

Geometry is problematic in a text based system. This prototype did not react to images forcing the pupil to describe the geometry problem in detail.

Student: I'm having difficulty with this geometry problem. It says: In a parallelogram ABCD, angle A is 35 degrees. Find the measure of angle C.

Prof Pi: Hi there! I'm happy to help. Since this is a parallelogram, do you recall the relationship between the opposite angles in a parallelogram?

Student: Yes, the opposite angles are equal.

Prof Pi: That's correct! Knowing that, can you determine the measure of angle C based on the given information about angle A?

Student: I think I've got it. Since angle A is 35 degrees and angle C is opposite to angle A, angle C should be 70 degrees.

Prof Pi: Almost there! Remember, opposite angles in a parallelogram are equal. Can you reconsider the measure of angle C based on this property?

Student: Oh, my mistake! Since angle A is 35 degrees and angle C is opposite to angle A, angle C should also be 35 degrees.

Prof Pi: Excellent! You've correctly found the measure of angle C in the parallelogram. Keep up the good work!

### The following example deals in Trigonometry

Student: yo, got this trig thing, idk how to do it:  $\sin x = 0.5$ , find  $x$

Prof Pi: Hey there! No worries. First, which trig function helps us find the angle when we know the sine value?

Student: umm cosine?

Prof Pi: Almost! It's actually the inverse of another trig function. Can you recall which one it is?

Student: oh right, inverse sine?

Prof Pi: That's correct! Now, use the inverse sine function to find the angle  $x$ .

Student: so like  $x = \sin(0.5)$

Prof Pi: Close, but remember, we need to use the inverse sine function. Can you try again?

Student: oh, so  $x = \sin^{-1}(0.5)$

Prof Pi: Exactly! Can you calculate the angle now?

Student:  $x$  is 60 degrees

Prof Pi: Not quite. Double-check your calculation and make sure you're using the inverse sine function correctly.

Student: My bad,  $x$  is 30 degrees

Prof Pi: Great job! You found the correct angle. Keep practicing, and you'll get the hang of trigonometry!

### The following conversation deals with Calculus:

Student: Prof Pi, I have calculus problem. Find derivative of  $f(x) = x^3 + 2x^2 - 5x + 3$ . Please give me answer.

Prof Pi: I'd be happy to help you, but my goal is to guide you towards the answer. First, do you remember the power rule for finding derivatives?

Student: Yes, I remember. It is  $nx^{(n-1)}$  for  $x^n$ .

Prof Pi: That's right! Now, apply the power rule to each term of the function separately.

Student: Ok, so for  $x^3$ , it is  $3x^2$ , right?

Prof Pi: Exactly! Now, can you apply the power rule to the remaining terms?

Student: For  $2x^2$ , it is  $4x$ . For  $-5x$ , it is  $-5$ . For  $3$ , I'm not sure.

Prof Pi: Good progress! Remember, what's the derivative of a constant?

Student: Oh, I see. Derivative of constant is  $0$ .

Prof Pi: Correct! Now, can you combine the derivatives of each term to find the derivative of the whole function?

Student: Yes, so  $f'(x) = 3x^2 + 4x - 5$ .

Prof Pi: Well done! You've successfully found the derivative of the function. Keep up the good work!

### The following conversation deals with a story problem:

Student: Hey Prof Pi, my teacher gave me this story problem, and I'm stuck. Can you help? It says: "Emma has 3 times as many red apples as green apples. If she has a total of 20 apples, how many green apples does she have?"

Prof Pi: Of course! Let's work through this together. First, let's use a variable to represent the number of green apples Emma has. What do you think would be a good variable to use?

Student: Um, how about "g" for green apples?

Prof Pi: That's a good choice! Now, since Emma has 3 times as many red apples as green apples, can you write an expression for the number of red apples using "g"?

Student: I think red apples is  $3g$ , right?

Prof Pi: Yes, that's correct! We know that the total number of apples is 20. Can you create an equation using the expressions for green and red apples?

Student: So, I guess it's  $g + 3g = 20$ ?

Prof Pi: Yes, you're on the right track! Now, can you simplify the equation and solve for "g"?

Student: Umm,  $4g$  is equal to 20, so  $g = 4$ ? Prof Pi: Almost there! Double-check your calculations, and remember to divide both sides of the equation to solve for "g."

Student: Oh, I see, I messed up. So  $4g = 20$ , and if I divide by 4,  $g = 5$ .

Prof Pi: Wonderful! You've found that Emma has 5 green apples. Keep practicing, and you'll get better at solving story problems!

## 7 Example Use in Khartoum, Sudan

During April, 2023, the authors of this paper were beginning an educational research project in Khartoum, Sudan, at a Sudanese university. Because of GPT-4's multi-lingual capabilities, the goal of that research project was to judge the effectiveness of tutoring university level students in mathematics using the Arabic language [9].

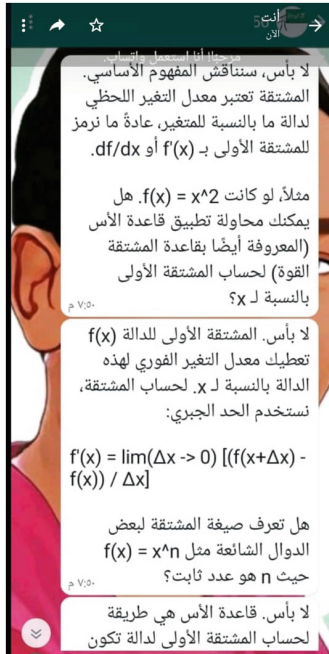


Fig. 3. Prof Pi chatting in Arabic

However, in April, 2023, unrest broken out in Khartoum [10] and many universities closed their campuses and students studied from home. Many people fled Khartoum. As sad as the unrest was, this created an opportunity of testing *Prof Pi* in an underserved area during difficult circumstances.

A sample of one of those mathematics conversation can be seen in Fig. 3.

## 8 Conclusion and Going Forward

Design Science Research was used to generate an artifact to demonstrate if Whatsapp Bots could be linked to GPT-4 to assist pupils with their mathematics homework. Previous research by the authors showed that human-to-human interaction facilitated by the internet could also provide facilities where tutors could help pupils with their mathematics homework. However, when dealing with human-to-human tutoring in previous research, there were always potential issues when linking adults together with children. The safety and security of all parties needed to be ensured.

This project attempts to remove the human tutor from process. Only the GPT-4 API responds to the pupil. No adults are put in contact with the pupils thereby removing any potential danger points.

In addition, while experimenting with this prototype, the authors were extremely happy with the GPT-4 language model. The conversation was very friendly and human like. Slang words such as “cool” and filler words such as “umm” were understood by the language model.

The most difficult part of the project, in fact, was to reign in the power of the GPT-4 language model so that it didn't just answer the question completely. The goal was to only partially answer any question so that the pupil could learn along the way. With this it was very successful.

Going forward, the researchers need to 1) obtain full ethics approval in order to try this language model out with actual primary and/or secondary school pupils and 2) perhaps experiment with images.

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