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Artificial intelligence in mathematics education through ODeL: An application of LOGO and GeoGebra software

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ABSTRACT

Artificial intelligence (AI) is a relatively new technological and methodological tool for use in the teaching and learning of subjects like mathematics, especially in developing countries such as Zimbabwe. The COVID-19 pandemic, online learning and 'working from home' concept have also necessitated the use of AI. AI has many applications in mathematics education such as predicting student performance, data capturing and storage, simulation, mathematical modelling, and problem-solving, among others. This study explores and describes the applications of AI in the open and distance electronic learning (ODeL) scenario through two examples: (a) A teacher who prepared a video lesson on geometrical transformations using AI software GeoGebra and posted the videos to her "A" level students on WhatsApp to learn independently. Then one of her students volunteered to illustrate on GeoGebra what he had understood from the teacher's lesson. (b) Another learner who modelled some interactive mathematical shapes and activities using the computer programming language LOGO. Further, unstructured questions were used to interview the participants and find out their opinions, comments and suggestions on the use of AI in mathematics teaching and learning through ODeL and in the comfort of one's home. Small vignettes of these participants are given in the study. Data were analyzed through emerging themes. Major findings indicated that, although both teacher and learners had positive views and beliefs on the use of GeoGebra and the computer program LOGO, they raised some challenges such as the need for more training and hands-on activities, the need to be equipped with ICT resources, and in some cases, to have strong and reliable Internet connectivity. Findings of the study could be used to inform policy and practice using AI in mathematics education through ODeL, especially post-COVID-19 era.

Keywords: artificial intelligence, COVID-19, deep learning, GeoGebra, LOGO, machine learning, mathematics education, ODeL

INTRODUCTION

Artificial intelligence (AI) is a relatively new technological and methodological tool for use in the teaching and learning of many subjects like mathematics, especially in developing countries such as Zimbabwe. The COVID-19 pandemic, online learning and 'working from home' concept have also necessitated the use of AI. AI has many applications in mathematics education such as predicting student performance, data capturing and storage, simulation, mathematical modelling, problem solving, to name a few. AI can come in the form of computer programming languages and computer interactive software such as LOGO and GeoGebra.

The AI software LOGO and GeoGebra and their advantages will be discussed under the review of related literature. However, there could be some challenges related to the use of AI such as job displacement, violation of personal privacy, AI generated fake news, among others (Arakpogun et al., 2021; Perez-Suay, 2022).

Statement of the Problem

Despite AI being advantageous and having gained prominence in Zimbabwe quite recently, there seem to be many challenges related to its use by both students and teachers during the learning and teaching of mathematics.

Purpose of the Study

The purpose of this study is to demonstrate the use of AI technological software GeoGebra and LOGO in the teaching and learning of transformations of trigonometrical functions and programming in LOGO. The study also aims to investigate the

challenges and benefits related to the use of these AI software. The demonstrations are done in open and distance electronic learning (ODeL) scenario.

Research Objectives

This study was guided by the following research objectives:

1. To demonstrate the application of AI software GeoGebra by a teacher and her students in the ODeL scenario.
2. To program in LOGO a mathematical interactive activity by a 'working from home' student.
3. To investigate the challenges and benefits encountered by the students and their teachers when using GeoGebra and LOGO AI software.
4. To suggest solutions to the challenges mentioned above.

REVIEW OF RELATED LITERATURE

This review of related literature is divided into the following sections: what is AI?, challenges and disadvantages of AI, benefits and opportunities of AI, what is GeoGebra?, and what is LOGO?

What is AI?

AI is a process that produces human intelligence through machines (Mohamed et al., 2022). It can also be considered as the theory and development of computer and machine systems that are able to perform tasks requiring human intelligence, for instance, visual perception, speech recognition, decision making, translation between languages, among others (Huang & Zhang, 2021; Miao et al., 2021; Mohamed et al., 2022). So, one could say AI is the 'intelligence' of machines and other objects. What about 'intelligence' of non-human animals, if at all they have that intelligence? Can it be called 'artificial'? This could be a subject for further research.

Machine learning (ML) allows a machine to 'learn' autonomously from past data and does not depend on explicit programming. ML uses algorithms that exploit big amounts of data to automatically come up with some patterns and models, for example, prediction of student performance using ML (Dhilipan, 2021; Miao et al., 2021: Van Vaerenburgh, 2022). ML is a branch of AI and computer science that uses algorithms and statistical models to analyze and draw inferences from patterns in data-imitating the way that humans learn (Arora, 2018; Deisenroth et al., 2020;Van Vaerenbergh & Pérez-Suay, 2022).

Deep learning (DL) is a type of ML that uses neural networks (modelled on human brain and nervous system) to learn from data. For instance, it may involve image classification and image labelling, development of drugs, playing computer games and board games; sometimes outperforming human beings (Berner, 2022).

Hence, AI is a wide but relatively new area of study that has not been sufficiently exhausted. The use of AI in the teaching and learning of mathematics (and statistics) and also, in the context of ODeL is widely believed to be beneficial but is not without its own challenges.

Challenges and Disadvantages of AI

Several challenges or disadvantages of using AI have been documented. According to Mohamed et al. (2022), sometimes answers given by students are not included in the AI systems' answers. AI may use huge and confidential data about students and their teachers, thus infringing on their privacy and data protection (Arakpogun et al., 2021; Mohammed et al., 2022). As mentioned before, AI can also replace or displace employees, including mathematics teachers and make them more or less redundant, especially more in the global south than in the north where AI is more advanced (Arakpogun et al., 2021; Van Vaerenbergh, 2022).

AI can disrupt economic activities in industries, leading to socio-economic inequalities. There are also huge gaps related to funding between Africa and developed countries (Arakpogun et al., 2021). Generally, it is believed that many students and teachers in developing countries, including Zimbabwe, need to be trained on the use of AI in the learning and teaching of subjects such as mathematics and statistics. The use of AI can sometimes lead to security risks which may also fuel the arms race (Wylde, 2023), therefore calling nations to consider appropriate actions for mitigation.

Benefits and Opportunities of AI

AI has been used for online asynchronous individual learning. So, ODeL institutions can and should improve their online learning by making use of AI (Rugube et al., 2023; Yeonjeong & Min, 2024). Several advantages of AI have been documented. For instance, Mohamed et al. (2022) say AI:

(1) boosts student communication,

(2) allows students more time to pursue interests outside of school, and

(3) helps students to be more innovative and creative.

AI acts as supplementary assistant to providing learning technologies that promote effective interaction with students; it is a guide or pedagogical agent and can be used for assessment and feedback (Yeonjeong & Min, 2024).

In the African context opportunities of AI include:

(1) letting children learn AI at school equips them with skills relevant for 4th Industrial Revolution,

(2) encouraging AI start-ups in African countries,

(3) encouraging women in ML and data science since they have been marginalized in this respect,

(4) improving employment and advancing medicine and socio-economic development, and

(5) improving agricultural productivity, etc. (Arakpogun et al., 2021).

What is GeoGebra?

GeoGebra is a freely downloadable and accessible dynamic, interactive and user-friendly software that was designed by Hohenwarter et al. (2009) as part of his masters' thesis (Leelavardhini, 2018). GeoGebra comes in many languages and versions and can be used by students and teachers to simulate, model and solve problems of various mathematical and statistical topics It can be used online as well as offline and thus fits in with the ODeL scenario whereby the learner sometimes only needs a computer or laptop without Wi-Fi or Internet connectivity. Some software applications with GeoGebra include CAS and dynamic geometry (Leelavardhini, 2018; Ljajko, 2013).

What is LOGO?

LOGO is another free programming software suitable for learning by primary school children and even teachers and adults (Bens & Bens, 2014; Gebauer et al., 2014; Solomo et al., 2020). It is low cost, easy to understand, user friendly, usable online or offline and the first step to computer programming (Bens & Bens, 2014; Solomon et al., 2020). LOGO was designed in the 1960's by Papert (n. d.).

LOGO also enhances cognitive skills, creativity, planning and problem solving (Pardamean et al., 2015). Logo programming can change the way learners think and solve mathematics problems and enhances creativity and achievement (Clements, 1985; Clements & Meredith, 1992) and is also a popular tool for teaching STEM concepts as well as being used to create tutorials (Sutherland, 1994, p. 179). Thus, it is also an AI tool suitable for teaching and learning in both ODeL and non-ODeL scenarios.

Conceptual Framework

It is noted that DL is an aspect of ML and ML is an aspect of AI. Mathematics teaching and learning can encompass AI, ML, and DL and can be done in the context of ODeL. Teachers and learners can use the software, GeoGebra, and the programming language LOGO to learn about trigonometrical transformations (at advanced level) and about shapes, colours, tones and movements (at primary or lower secondary levels) as may be necessitated by COVID-19, 'working from home' and other factors. **Figure 1** gives the conceptual framework showing the relationship among mathematics teaching/learning, ODeL, Al, ML, and DL.

METHODS AND ACTIVITIES

This study explores and describes the applications of AI in the ODeL scenario through two examples:

1. A teacher, purposively selected, prepares a video lesson on geometric transformation using the free computer software, GeoGebra. She first recites the video lesson herself in the comfort of her home before posting the video to her advanced level students on WhatsApp, so that they could learn the aspect of geometrical transformation in the comfort of their own homes. The first researcher observed the teacher's video lesson and made a follow up by asking one of the learners to volunteer and prepare his own video explaining what he had learnt from the teachers' demonstration video lesson.
2. The first researcher's niece had been asked by her teacher to come up with a interactive computer game or activity during the school term holiday as an assignment for continuous assessment for learning. The researcher and his niece used the LOGO computer program to produce a flag and to 'spin the flag'. A programmed 'national anthem' could be sung, as the flag was being raised or spun. To solicit more information, three other mathematics teachers and three students were conveniently selected and requested to respond to unstructured interview questions to find out their opinions, comments and suggestions on challenges, benefits and their experiences when using AI in mathematics teaching and learning from home (i.e., through an aspect of ODeL). Small vignettes of these participants are given in the study. Data were analysed through emerging themes.

RESULTS AND FINDINGS

GeoGebra

The GeoGebra videos for the teacher are available upon request.

The videos for the learner could not be posted here because the learner was a minor and parental consent was not given. However, the learner clearly demonstrated and explained using GeoGebra the translation, reflection, and enlargement of trigonometrical functions.

Activities carried out were as follows:

1. Sketch and describe the following graphs $y = cos(x), y = -cos\,(x), y = cos\,(-x), y = cos\,(2x)$, and $y = 3cos\,(x)$.The results were shown on the GeoGebra interface.
2. Explain your own attitude and behavior on and about the AI software GeoGebra.

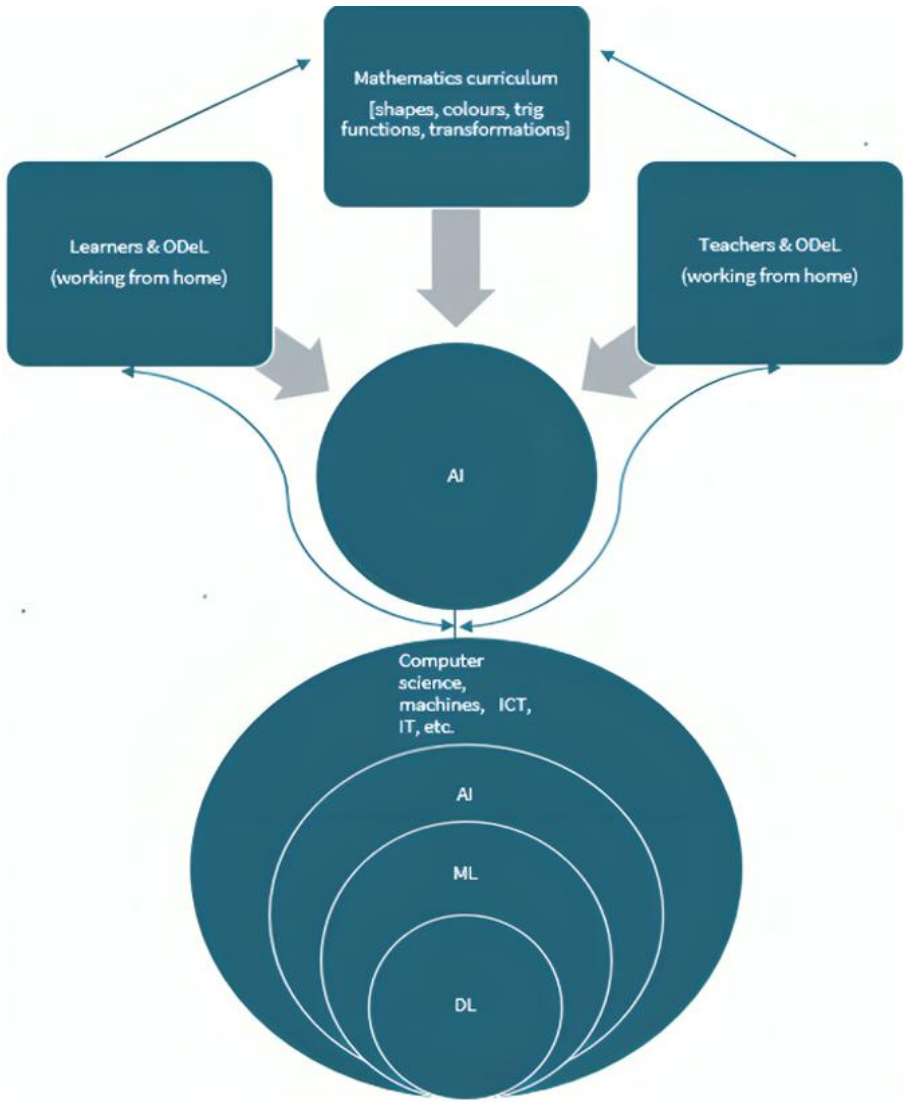

Figure 1. Conceptual framework showing relationship between mathematics teaching and learning, ODeL, AI, ML, and DL (Source: Authors' own elaboration)

The teacher explained that GeoGebra helped to explain the teaching and learning of transformations such as translation, reflection, rotation, and enlargement of cosine and sine functions, hence it could be used as a tutor. The researchers noted that GeoGebra was interactive and could be used offline, alone or with someone, hence suitable for the ODeL. The researchers also noted that, although GeoGebra could be used as a tutor, it could not completely replace the teacher who had to verbally explain (also with body language) some of the difficult concepts and equations.

On the other hand, the learner explained that GeoGebra was interactive and fun and enhanced creativity and the use of color. He said that the purpose of GeoGebra was to solve geometry problems and to model real life situations. The learner was happy and motivated to be captured by the videographer although his parents could not give permission to share the videos with everyone.

LOGO

The LOGO programs were as follows:

Student task: Use AI in the form of the computer programming language LOGO to model some interactive mathematical shapes and activities.

Student's answers:

I will ask LOGO to draw a triangle, a flag and to spin the flag 'SPINFLAG' through the following programs.

To TRI

Repeat 3 [FD 40 RT 120]

END

The triangle ... is drawn

[demonstrated live on LOGO program]

To FLAG

FD 40 TRI BK 40

END

Now we spin the flag

To SPINFLAG

Repeat 8 [FLAG LT 45]

END

We have this nice diagram ...

[demonstrated live on LOGO program]

We may color our flag or the 'spinflag' in different background colors (BG) of our choice. For example,

SETBG 1 or SETBG 4 (we may choose colors from 1 to 15)

We may use PR BG calling for BG color number

Or PR PAL pallet color no

Or PR PC pen color no etc.

Example:

CS

Make color 0

Repeat 36 [LT 10]

Repeat 8 [FD 100 LT 45]

Make color color + 1

SETPC color]

Activity: Design an AI program that 'sings' a song (national anthem) of your choice when the flag is being 'raised' or when the spinflag is being rotated ...

Student's response:

We then have these LOGO programs that 'sing':

To sing

TONE 988 899

Repeat 3 [TONE 1000 900 TONE 900 800 TONE 800 700 TONE 600 500]

TONE 750 534 TONE 622 356

Repeat 2 [Tone 655 488]

Repeat 3 [Repeat 2 [Tone 355 766] Repeat 2 [TONE 988 899] Repeat 2 [Tone 655 488] Repeat 2 [TONE 1000 766] Repeat 2 [TONE 552 667] Repeat 2 [TONE 800 700]]

We may try various and different numbers to produce different sounds until the computer more or less sings 'our national anthem' as our 'flag' spins or changes color.

Interview Responses

Learners' and lecturers' views on the use of AI

Here are a few cited short vignettes from the learners (LN) and the teachers (TR):

LN3: When working at home, there is uncontrolled disruption from siblings.

LN1: Sometimes it's difficult and not possible to contact the teacher for help.

LN2: GeoGebra is user friendly and can teach me what I did not know about transformation of trig functions.

TR2: We have this feeling of ownership of the LOGO project and activities.

TR1: Balancing time with other activities is a challenge.

LN1: Logo increases my motivation to try new things.

TR3: Am no good at drawing, but GeoGebra helps to produce neat and clear figures and diagrams.

All the learners and teachers' responses to the short interview were summarized and are given in the thematic **Table 1**.

Table 1. Responses to the interview questions

Question	Responses		Emerging themes
	Teacher	Learner	
1. Briefly explain what you understand by AI	-Imitation of human reasoning by computer -Use of computer to do man's job -Using computers to think like human beings -Programmed and computerized models	- AI is whereby computers are used to perform tasks done by humans. - A program designed to satisfy any user's requirements. - Use of technology in performing human functions and to think like human beings. - Ability for computers to do what humans actually do. -The use of machines such as robots to solve different problems.	**Teacher:** (a) computer doing man's job & (b) computer programmed models **Learner:** (a) computer or technology doing man's job & (b) program satisfying user requirements and solving problems using machines
2. What aspects, skills or concepts of AI or ICT can be used in the teaching and learning of mathematics?	-Computer programming and mathematical calculations - Almost all–graphing, linear maths, differentiation, and integration - Computer aided learning and Apps that can calculate math problems for you	- All basic tools - Use of chat boards to teach how to solve math problems from basic concepts - Gives a lot of questions and well-defined answers (so that you can grasp concepts better) - Both (AI & ICT) can be used as resource persons instead of the actual person, that is through the use of video lectures	**Teacher:** (a) computer programming & math calculations used in teaching or learning math & (b) all maths topics can be taught with AI. **Learner:** (a) basic tools/chat boards can be used to solve math problems & (b) use of AI & ICT as artificial resource persons.
3. Have you used either AI, computers or ICT to teach or learn mathematics before? Briefly describe your experiences.	-Yes, have used CD-based Web resources, flipped pedagogy proved to be helpful to learners -Yes, I could repeat same problem until I grasped the answers - Yes, used GeoGebra & (leaners) student teachers enjoyed it, also used calculators - Yes, at tertiary level students concentrated on writing notes than on explanation	- Yes, I learnt more math skills & formulas. Makes it easy to cover topics - It is helpful, but it only gives you the formula for a certain math question and not the procedure -Yes, I used Gemini, Black Box, & Poe to solve algebraic equations. However, on some questions I got wrong workings but correct answers - Yes, I am one of the developers of AI models. I developed Lucy Virtual Assistant on Google Playstore - I have made use of ICT mostly and it is always helpful, learners usually want to see for themselves, and for mathematics, video lessons are effective because learners will be learning while being entertained. Everyone wants to see thereby improving concentration among all the learners.	**Teacher:** AI is helpful to learners. **Learner:** (a) AI is helpful, solves problems, and assists in modelling & (b) development of AI Virtual Assistant model on Google Playstore
4. (a) What challenges did you face when you were teaching or learning mathematics using AI, computers, ICT or computer software? (b) Mention the software and the challenges.	Challenges: (a) poor network connectivity: -software: Web resources, (b) challenge-network: -software: ChatGPT, (c) challenge-scarcity of resources & learners unfamiliar with these gadgets - software- Minitab 17 & Lingo	Challenges: (a) requires money to buy data -software: Logo (b) Got wrong answers but correct working - Software: Gemini, (c) No option to write on it but only to scan printed math documents -software: PhotoMath, (d) No projector only a laptop, lack of knowledge on using all the equipment included in the software -software: GeoGebra	**Challenges**: **Teacher:** (a) scarcity of resources and poor network (b) Usable AI Software–web resources ChatGPT, Minitab and Lingo **Learner:** (a) lack of knowledge to use the software (b) Usable AI Software–Logo, Gemini, PhotoMath, GeoGebra

Table 1 (Continued). Responses to the interview questions

Question	Responses		Emerging themes
	Teacher	Learner	
5. (a) What do you think are the benefits or opportunities of using AI and/or computer software in the teaching and/or learning of mathematics? (b) Mention the software and the benefits or opportunities	Benefits: (a) learning is more student centered & interesting -Software: ChatGPT, (b) fast method, can learn at own pace, cheap-no need for tutor for extra lessons Software: GeoGebra, (c) visual aspect, move fast with concept development Software: MINITAB, (d) easy calculations for volume data, can sometimes interpret data accurately -software: GeoGebra	Benefits: (a) Shows full stages & solutions for asked math questions -software: Logo (b) teaches basic concepts, gives step by step format on how to solve math problems -Software: Gemini (c) its 99% accurate, making possible to revise for exams Software: PhotoMath (d) learning is made fun, explanation of concepts made easier, reduces expenses in the case that resource persons are no longer hired but are readily available on the Internet, an opportunity to showcase one's ability to solve problems is created because one can also start making videos and post them -Software: GeoGebra	**Benefits:** **Teacher:** Learning as more student centered, fast, cheap & suiting ODeL **AI Software**–ChatGPT, GeoGebra, Minitab, **Learner:** (a) -AI as fun, giving full & step by step stages of solving problems, -student can do it alone (fitting ODeL) (b) replaces human resource persons-, learner does it alone (ODeL) (c) through showcasing one's ability & creativity, learners can make videos and post them **AI Software:** Logo, Gemini, PhotoMath, & GeoGebra
6. Write any other comments or suggestions about the teaching and learning of mathematics using AI or software such as GeoGebra and LOGO	-One to have IT skills -Learners to have smart phones -GeoGebra is very versatile & easy to use -does not clearly give an 'outside machine' or human analysis	-Logo makes teaching and learning easy -Logo can be freely accessed & used anytime -GeoGebra can be utilized to create own math activities & resources, learners can join GeoGebra communities in discussing math problems, -With Logo learners can create programs to solve geometric problems, calculate areas & solve math problems through programming -GeoGebra is more convenient, allows teachers & students to explain and learn math; it's more than just a tool. - GeoGebra requires one to be educated on how to use the software; it's a very good software to use on topics to do with graphs and circle theorems	**Suggestions:** **Teacher:** (a) need for IT gadgets and skills training (b) AI does not give 100%, human or 'outside machine' analysis **Learner:** (a) there is free access, & can be used anytime (ODeL) (b) can create own resources (open) (c) need for one to be educated on AI & the software

DISCUSSION OF FINDINGS

In this study, both learners and teachers were motivated and willing to talk about AI. Those who were given some tasks creatively programmed with Logo and produced interesting shapes, colors and tones (songs) while with GeoGebra the learning of transformations of trigonometrical functions was made easy. Participants were of the positive views that AI was interesting and could be used to play games, to model and solve mathematics problems, among others. These views corroborate those of Yeonjeong and Min (2024), Rugube et al. (2023) and Mohamed et al. (2022). However, negative sentiments or challenges also echoed. For instance, lack of resources, lack of expertise, infringement on peoples' rights and privacy, job replacements and anxiety about adopting the AI were mentioned. They corroborate views of Wylde (2023), Van Vaerenbergh (2022), and Arakpogun et al. (2021), among others.

CONCLUSION

This study concludes that AI has its advantages–it is sometimes free, interesting, interactive, cheap, creative, practical, and can be used as an assistant tutor. The disadvantages include the failure to completely replace the human being, sometimes students copy and paste hence there could be too much–plagiarism since some students are lazy to think, some people may lose their jobs, and sometimes AI is unethical.

Recommendation/Way Forward

This study recommends the followings:

1. Institutions should be well equipped with AI technologies.
2. Students and staff members should be well trained and inducted on the use of AI.
3. There should be a change of mindset–to accept and brace AI but being warry of its 'negatives.'
4. Computer science should be taught early in schools and programming should be integrated into the mathematics curriculum.
5. The country at large should create and build a national AI strategy/policy to enhance mathematics teaching and learning, among other subjects.

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

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

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