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Using ChatGPT for the Acquisition of Computational Thinking Skills: A Case of African Indigenous Games

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ABSTRACT

This paper proposes using a ChatGPT¹-generated algorithm for an indigenous game to mediate the acquisition of computational thinking skills. The paper seeks to answer the question: How can the ChatGPT-mediated algorithm for indigenous games foster the acquisition of computational thinking skills? Using a Participatory Action Research approach, 19 collaborators from 11 African countries gathered 185 indigenous games. The paper focuses on one of those games that is played in all 11 countries. The paper concludes that involving collaborators, who are indigenous members of their communities and have experiential knowledge of the game, led to their acquisition of computational thinking skills.

Keywords

ChatGPT, indigenous games, game-based learning, algorithms, computational thinking.

INTRODUCTION

One of the major challenges facing educational systems in developing countries is how to effectively impart the logical thinking skills necessary to develop digital products rather than just consuming products created by Western developers. The absence of responsive, transformative education systems, built to recognize African students' prior knowledge, makes this more challenging. Instead, traditional pedagogical approaches that promote rote memorization and rigid assessment methods continue to be prevalent in African schools and higher education institutions.. This paper argues that not only are computational thinking skills required to transform education systems in Africa but leveraging generative artificial intelligence to teach computational thinking skills could also prepare the next generation to propel Africa's development. Historically, despite many reforms, Western education systems have largely been adopted and even imposed upon indigenous African people with little

¹ ChatGPT is a virtual assistant Chatbot developed by OpenAI and launched on November 30, 2022.

consideration of existing Indigenous Knowledge Systems (IKS). As Pihama and Lee-Morgan (2019) pointed out, these educational systems were initially designed to advance the colonial endeavor rather than to foster computational thinkers. Despite the liberating and transformative nature of education, which opens many doors and provides many new opportunities, in many impoverished countries education reinforces stability and the existing social order (Gould, 1993). This implies that Africa remains a consumer of innovations developed in Western countries. While indigenous games, through their cultural capital and habitus, are known for their potential to enhance the accessibility and relevance of learning (Matsekoleng et al., 2022), only a few approaches leverage these cultural resources to reshape the indigenous learners' educational experiences.

Gould (1993) states that, "education has brought universalist ideas and knowledge of science and technology to many people but has been unable to produce new techniques and machines that put that knowledge to use." (p. 204)

This paper aims to combine ChatGPT (knowledge of science and technology) with computational thinking (universalist ideas) and indigenous games (cultural capital and habitus) to enhance curriculum instruction.

Liu et al. (2024) observe that, "generative Artificial Intelligence (AI) has become a prominent research focus in exploring innovative solutions to improve educational efficiency and effectiveness". (p. 169)

Thus, the paper seeks to answer the question: "How can the ChatGPT-mediated algorithm for an indigenous game be used to harness the acquisition of computational thinking skills?"

LITERATURE REVIEW

Indigenous Game-Based Learning

Game-based learning is an instructional approach that uses games as a teaching and learning tool (Jääskä et al., 2022). Numerous benefits of game-based learning have been reported. These include, improved educational outcomes and student learning processes (Adipat et al., 2021); increased engagement, motivation and active learning (Jääskä et al., 2022); more meaningful assignments for learners (Jääskä et al., 2022); students achieving enhanced mathematics learning success, confidence and enthusiasm (Hung et al., 2014); reduced stress (Zijing & Razlog, 2023); enhanced understanding of complex concepts in science (Khan, 2017); a positive effect on leadership and team-building skills (Tariq & Abonamah, 2021); the promotion of critical thinking, decision-making and metacognitive abilities (Plass et al., 2015); and stimulation for reflective learning (Lampropoulos et al., 2019; Young, 2018). Indigenous games have a significant positive effect on learners' physical, cognitive, social and cultural development (Roux, 2009). It has also been reported that these games can improve the understanding of, and motivation to study physics in the Philippines (Moro & Billote, 2023). They can cultivate cultural inclusivity and social cohesiveness among pupils and can promote cultural expression and identity, and hence can also counter Eurocentric curriculum principles (Hadebe-Ndlovu, 2022). These kinds of games can cultivate culturally relevant skills while applying technologies equitably and ubiquitously to indigenous communities; this promotes the decolonization of educational technology. This technology functions as a reflective and generative algorithm platform for constructing and deconstructing indigenous knowledge. In support of perspectives reflected in recent research (for example, Madima, 2021; Kim & Johnson, 2021), we assert that educational technology encourages the acquisition of 21st-century skills. Additionally, the effective application of ChatGPT to generate logic for indigenous games could function as an effective form of Indigenous Game-Based Learning (IGBL) to teach computational thinking to indigenous communities.

Computational Thinking Skills

Jeannette Wing (2006) coined the phrase "computational thinking". Wing (2006) asserts that mastering this type of thinking is a crucial skill that enables individuals to address challenges and develop systems that were previously beyond their capabilities. There has been an expansion on the Computational Thinking (CT) skill set as depicted in Table 1.

Table 1:

Expanded computational thinking skill set

Expanded skill set	Explanation	Author
Algorithmic Thinking	Algorithmic thinking refers to a series of ordered steps and step-by-step solutions to problems.	(Barr et al., 2011; Angeli & Giannakos, 2020)
Operational Skills	Operational skills encompass simplifying, embedding, transposing, and simulating.	(Rafiq et al., 2023)
Mental Processes	These processes are essential for solving practical problems.	(Yildirim & Uluyol, 2023)
Complex Problem Solving	The ability to solve complex problems involves problem decomposition, which entails breaking down intricate issues into simpler components.	(Rafiq et al., 2023; Angeli & Giannakos, 2020)
Structured Thinking	Thinking computationally plays a significant role in problem-solving. It embodies structured thinking.	(Rafiq et al., 2023; Angeli & Giannakos, 2020)
Multiple Ways of Knowing	Engaging in practices that lead to multiple ways of knowing is essential for holistic understanding.	(Brennan & Resnick, 2012)
Problem-Solving Strategies	Effective strategies for understanding and addressing problems are fundamental to success in various fields.	(ISTE, 2023)

While these skills are crucial, efforts to develop them remain unsatisfactory in numerous educational systems across the African continent. On the other hand, universities globally are increasingly focusing on developing computational thinking skills (Kang et al., 2023). This includes the ability to solve practical problems efficiently and effectively (Yildirim & Uluyol, 2023). These are a 21st-century competence expected of future professions (ibid.). Computational thinking is included in mainstream curricula in the United States and the European ministries of education (Ezeamuzie & Leung, 2022). Nevertheless, more work is required to integrate it into African curricula. Rafiq et al. (2023) observes

that although computational thinking enhances students' problem-solving skills, educators lack pedagogical knowledge to effectively teach CT and research is still emerging.

Jocius et al. (2020) developed a 3C model (i.e., Code, Connect, and Create) to support teachers in integrating computational thinking into their classrooms. Similarly, the ADAPTTER framework (Activities, Demonstrations, Application, Pre-activation, Transparency, Theory, Exemplification and Reflection) was designed for teaching and learning of computational thinking involving Irish second-level teachers and students (Kirwan et al., 2022). Focusing on a developing-economy context, the PD4PCT framework was developed to assist primary school teachers to integrate computational thinking into teaching and learning (Ausiku & Matthee, 2023). A bibliometric analysis evaluated, analyzed and discussed academic journal articles on computational thinking published between 1987 and 2023 and concluded with a call for research to understand ways of developing learning strategies for effective acquisition of computational thinking skills.

Future research should concentrate on developing and implementing various learning strategies to assist students in developing their subject knowledge and mastering complex skills such as critical thinking and problem-solving. Developing and implementing these learning strategies should be a primary focus of future research. (Rafiq et al., 2023, p.717)

This paper heeds this call and aims to leverage ChatGPT to teach computational thinking skills based on indigenous games.

Generative Artificial Intelligence (GAI)

In contrast to the natural intelligence exhibited by humans and other animals, such as learning and problem-solving, artificial intelligence (AI), also referred to as machine intelligence, is intelligence demonstrated by machines (Baum, 2023). These machines are designed to imitate human intelligence for task execution. The design involves the classification of numerous commands according to a categorization set by the researcher or website designer. For example, voice-activated smartphone assistants can be prompted to search for and retrieve information based on the program settings. At the same time, customer service chatbots that appear on company websites assist users with specific product inquiries. AI research in computer science is the study of "intelligent agents," or any technology that senses its surroundings and makes informed decisions to increase the likelihood that it will achieve its goals (Baum, 2023). Baum (2023) explains a relatively new area of AI, known as generative AI (GAI), where machines become co-creators. The GAI model can generate predictions based on the immense amounts of information fed to technology by researchers. GAI can analyze existing data and generate new text, pictures, videos, or programming codes in response to commands or prompts input by the user (Brühl, 2024). Computational methods that can produce ostensibly original and meaningful content, for example text, images, or audio, from training data are referred to as generative AI methods. Several free AI content generation tools that make use of a Large Language Model (LLM) are available; these include Microsoft Copilot (<https://copilot.microsoft.com/>), Gemini (<https://gemini.google.com/app>), Claude (<https://claude.ai>) and ChatGPT (<https://chat.openai.com/>). In the research reported on in this paper, the LLM of ChatGPT was used to generate the text of an algorithm based on a prompt describing an indigenous game.

The emergence of AI in education has placed education at a crossroads with two potential pathways: "First, AI has the potential to revolutionize existing teaching methods, assessment, and learner engagement. Second, AI also can create an entirely new education system." (Dawson et al., 2023, p.1051). Farrelly and Baker (2023) suggest that instead of concentrating on the disruptive impact of

Large Language Models on higher education and society, efforts should be aimed at creating frameworks that enable both students and educators to leverage the potential of Generative AI.

While rule-based AI systems execute predefined instructions or rules, generative AI models learn from large datasets to generate new content (Ng et al., 2024). Gibson et al. (2023) argue that AI is a magnifier; it can make the bad worse or the good better and must be used with that understanding in mind. They further elaborate, "AI in education is undoubtedly a double-edged sword that can lead to unintended consequences and will likely cause a rethinking of many assumptions about learning, knowledge, skill, performance, creativity, and innovation." (Gibson et al., 2023, p.1128)

According to Dawson et al. (2023), there is a need for "new frameworks, models, and ways of thinking; ones that include the presence of non-human agents that are more like an active partner than a simple technology, resulting in important questions about revising existing team-based and collaborative theories of learning." (p.1051)

In a student self-regulated learning and science education study in Hong Kong it was concluded by Ng et al. (2024) that "by leveraging the power of generative AI, chatbots can help students develop their self-regulation skills, such as planning, acting, and reflecting, which are essential for success in science and other academic domains." (p.20)

In this paper, the authors view indigenous games as non-human agents that serve as active partners in acquiring computational thinking skills.

THEORETICAL UNDERPINNING

The seminal work introducing Social Learning Theory (Bandura, 1977; Bandura, 2003) identifies three related constructs: modelling, efficacy and parasocial interaction; these are fundamental to this paper. Modelling describes behaviors that are too complex to be explained effectively without demonstration or illustrations. The computational thinking involved in indigenous games is such a concept and algorithms generated by ChatGPT, based on game dialects, serve to model this process. Efficacy is enabled by pre-existing experiential knowledge of indigenous games, furnishing the requisite social capital for analyzing the algorithm. Parasocial interaction occurs when an algorithm is revised because of an algorithm critique, thereby signifying transferable and practical knowledge acquired that can be applied to other contexts, such as other indigenous games.

METHODOLOGY

Participatory Action Research (PAR) was used as a dynamic and transformative research approach that has proved to be very useful in developing countries, notably South America (Bhana, 2006). Unlike traditional research paradigms, where researchers observe and study communities from an outsider's perspective, PAR emphasizes active collaboration between the researchers and community members. Several guiding principles set PAR apart from conventional research methodologies. To improve social, educational, and material conditions, PAR's primary goal is to produce knowledge in collaboration with those who the research will most directly impact (Bhana, 2006). Cornish et al. (2023) describe PAR as an approach in which participants experiencing a problem utilize emancipatory social change to conduct research and generate new knowledge. According to Cornish et al. (2023), PAR is guided by four principles: Principle 1: Leverage the experience of participants; Principle 2: Learn through experience - knowledge in action; Principle 3: Research as an empowering and transformative process; and Principle 4: Collaboration through dialogue. PAR is a fundamental driver for community participation (Bhana, 2006). It actively involves community members in shaping research questions, data collection, analysis, and decision-making processes.

In the project reported on here, participants were indigenous members of their communities in their respective countries and were members of the OERiGA² project team. Hence, they were involved in shaping the research questions, data collection and analysis of the data.

There were several reasons why collaborators (ICM - Indigenous Community Members) from African countries joined and continued to participate in the project, which they explained as follows:

“Danger of losing indigenous games if they are not well documented...learning through play...is the central activity in developing these children cognitively.”

“Indigenous games are an important catalyst for digital game developers to create and design authentic context-specific games and platforms.”

“Project seeks to explore indigenous children's games as a means for an authentic engagement with computing rooted in the African experience.”

“We are losing our cultural heritage, and our kids are only exposed to Western culture.”

“Potential for sustainable context-specific games for African children, which might be facing extinction due to exposure to Western ideologies.”

“Indigenous games pass down cultural values, virtues and, frown on vices through songs, proverbs, riddles and educate the participants on their people’s way of life.”

“The value of indigenous games can additionally be seen in the potential benefits it brings to teaching and learning.”

“The love of the culture that is being lost. The perceived value of the project. It is the pioneer in this aspect.”

Nineteen collaborators (42% male and 58% female) from eleven African countries were invited to join the project (see Figure 1). The age group of collaborators (participants) ranged from 31 to over 51 years old (see Figure 2).

Figure 1:
Participants by Gender



Figure 2:
Participants by Age Groups



² (<http://etilab.uct.ac.za/oeriga/>)

Figure 3:
Participants by Country

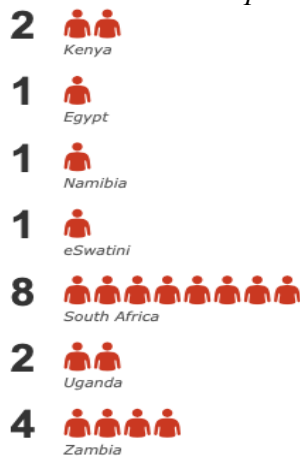


Figure 4:
Participants by Occupation



Participants came from seven countries (see Figure 3 above) and participated in the study reported in this paper. Consistent with the PAR methodology, participants were active members of the project and were instrumental in shaping the research objectives, as well as data collection related to games, analysis and dissemination of results. Participants were indigenous members of their communities in their respective countries.

In contrast to a hierarchical approach where researchers study a community, PAR emphasizes knowing others rather than about them. Knowledge is reconceptualized as a shared entity, breaking down traditional barriers. The collaborators were indigenous members of their communities and contributed information about the games they played during their childhood; hence this is “Ethnocomputational creativity” (Bennett, 2016: p.598). Ethnocomputation is the process of using cultural or traditional knowledge (like indigenous games) to create something valuable, such as a 21st century skill. The key idea is that the value or benefits generated from this process go back to the community that originally created that cultural knowledge. It's different from ethnocomputing, which looks at how different cultures influence the way we think but doesn't focus on giving value back to the community (Tedre et al., 2006; Babbitt et al., 2012; Bennet, 2016).

Using PAR, collaborators co-created knowledge of indigenous games, and while ChatGPT mediated the creation of new knowledge for the acquisition of computational thinking skills for the benefit of the indigenous community members.

Through monthly project meetings, collaborators shaped the project's objectives, designed the research instruments, and served as participants. One of the indigenous games is played in 11 African countries. Figure 5 depicts names used for the same game in different African countries.

Upuca serves as an illustrative example of an indigenous game that is played in South Africa and 10 other African countries, each with its own distinct dialect. There are 14 dialects of the Upuca game. Although the dialects vary, the game mechanics are similar, and it is therefore a useful game for indigenous communities from 11 countries to debate the algorithm of the game. Figure 5 depicts names used for the same game in different African countries.

Figure 5

OERiGA Wheel of One Indigenous Game with many Dialects



ChatGPT was used for generating algorithms and offered a clear language for understanding the logic of the game. These algorithms were shared in the Google Classroom for discussion, adaptation and

validation. Google Classroom functioned as a platform for both construction and deconstruction of knowledge. Participants demonstrated an understanding of the game's rules and engaged in conversations regarding the associated processes. This was in contrast with Western education where such recognition of local knowledge is often absent and fails to effectively engage students due to the perceived complexity of algorithmic comprehension. Seven algorithms were produced and published within the Google Classroom. One of the algorithms is presented in Table 2.

The narrative describing the interaction of players participating in an indigenous game (see Table 2) was used as the basis for the algorithm (see Table 3) which was then used to construct a model of the game. Subsequently, this model was evaluated for its effectiveness by indigenous communities familiar with the game.

Table 2:

Upuca played in South Africa

Prompt
Write an algorithm for the Upuca Game: 1. Set up a circle on the ground and place stones inside the circle. 2. The game is played by two players at a time. 3. Each player has one larger stone, known as a ghoen. 4. The player throws the ghoen in the air and simultaneously removes stones from the circle. 5. After throwing the ghoen, the player then pushes the remaining stones back into the circle, leaving one or more stones outside, depending on the game level. 6. The game levels correspond to numbers such as 1s, 2s, 3s, 4s, 5s, etc. 7. The objective is to not drop the ghoen and to collect the correct number of stones for the next level. For example, at level two, the player must collect two stones. 8. If a player fails to catch the ghoen, the game moves to the next player. 9. The winner is the player who collects the most stones from the circle. Note: This algorithm applies to the coordination game Upuca, commonly played in South Africa by boys and girls of various ages.

Table 3:

ChatGPT Generated Algorithm for Upuca

Basic algorithm for the Upuca game:
<p>1. Initialize Game Parameters:</p> <ul style="list-style-type: none"> - Set up a circle on the ground. - Place stones inside the circle. - Define the number of game levels (e.g., 1s, 2s, 3s, etc.). - Determine the number of stones to be left outside the circle for each level. <p>2. Player Setup:</p> <ul style="list-style-type: none"> - Assign two players to the game. - Give each player one larger stone, known as a ghoen. <p>3. Game Loop:</p> <ul style="list-style-type: none"> - While there are stones left in the circle: <ol style="list-style-type: none"> 1. Player 1 throws their ghoen in the air and simultaneously removes stones from the circle.

2. Player 1 pushes the remaining stones back into the circle, leaving the required number of stones outside according to the current level.
 3. Player 1 attempts to catch the ghoen.
 4. If Player 1 successfully catches the ghoen:
 - Check if the number of stones collected matches the level requirement.
 - If the condition is met, Player 1 advances to the next level.
 - If the condition is not met, the game continues at the same level.
 5. If Player 1 fails to catch the ghoen:
 - Player 2 takes their turn.
 - Player 2 follows steps 1-4.
 6. Repeat steps 1-5 until there are no stones left in the circle.
4. Scoring and Determining the Winner:
- Calculate the total number of stones collected by each player.
 - The player with the highest number of collected stones wins the game.
 - If there's a tie, the game can be extended with additional rounds or settled using a tiebreaker.
5. End of Game:
- Display the winner.
 - Optionally, offer a rematch or conclude the game.

This approach demonstrated how community members can develop computational thinking skills through practical application. The following programming constructs, which are common in all games, are illustrated in the algorithm given in Table 3: initializing game parameters, setting up players, game looping, repeating actions while there are stones left in the circle, conditional actions for decision-making, scoring and determining a winner, and concluding the game. The underlying assumption is that participants' familiarity with the indigenous game makes it relatively easy for them to comprehend the meaning of these constructs. Exposure to the algorithm therefore serves as an introduction to three programming principles: sequence - the order of instructions to be carried out, loops - instructions to be repeated, and conditional statements - to check conditions and make decisions based on the conditions. Understanding these concepts and their functionality is a crucial aspect of problem-solving that is challenging for learners to grasp fully when taught through traditional methods. The skills acquired through this process can be applied to the analysis of other indigenous games.

However, although the algorithm effectively portrays core gameplay elements, such as player turns and stone manipulation, it does not explicitly represent the level progression process based on the number of stones kept outside the circle, as detailed in Table 2. Furthermore, the algorithm diverges from the described gameplay by introducing a scoring system that is not included in the description, and by including a condition for the conclusion of the game that relates to an empty circle. This underlines the necessity for iterative improvement to the algorithm, to ensure exact alignment with the unique subtleties of Upuca as played in South Africa. Even though these problems exist, the algorithm does a

good job of explaining the basic ideas of Upuca. It builds a solid base for its computational use and shows how this approach could improve IGBL in a social learning setting.

ANALYSIS

Having received an invitation to the OERiGA Google Classroom, indigenous community members from participating African countries were tasked with evaluating an algorithm for the Upuca game, which is commonly played in South Africa (see Table 4). Participants were directed to critically appraise the algorithm and propose methods for enhancing its alignment with their interpretation of the game's rules.

Table 4:

A Google Classroom Activity

Task to critique algorithm
You played the following game: Namibia (Ondota), Zimbabwe (Nhodo), South Africa (Diketo Upuca), Lesotho (Magave), eSwatini (Inketo), Zambia (Chiyato Ichiyenga), Mozambique (Mathocosana Mathakuzana), Kenya (Mdako), Uganda (Mdako), Egypt (Alhasaa Alal) and Cameroon (Seven Seven)
Critique the algorithms in the Google Classroom and comment on the algorithm that best aligns with how the game is played.

A comprehensive analysis is given below.

Principle 1: Leverage the Experience of Participants

Modelling

Modelling is used to demonstrate behaviors that are too complex to accurately describe without a demonstration or illustration. Some variations were noted by the community members regarding how the game starts.

- Create an empty circle to hold the stones. (the circle or a hole must not be too big, it must be a size that fits all 12 stones).
- A small circle-like structure is dug on the ground, and then 12 small stones or seeds called 'mabako' are put in this tiny hole (akiina).
- The first player picks 1 stone from a circle drawn on the ground or from a hole and throws it. The stones inside the circle are initially 12.
- At the initial stage, indicate the number of stones to be in the circle, the number of players, and the mode of selecting who goes first.
- Decide on the number of players participating in the game ranging from 2 players...player 1 tosses the ghoen in the air, whilst it's in the air you use the same hand to scoop out all the stones before you catch the ghoen.
- Take one stone and throw it in the air. Pick up another stone from the floor quickly and catch the first one before it falls.

While the game may seem similar across various dialects, indigenous communities have distinct ways of playing it, which could be reflected in the algorithm generated by ChatGPT.

In Uganda's game dialect, the player to start the game is determined as follows:

To determine which player started 1st, one of the 2 or more players got a stone in her hand, hid the hands with the stone behind her back, put the stone in one of her hands, and brought forward her hands with folded fists. The other player(s) used probability to tap on one of the hands (there was a song to accompany the selection of the fist, which aimed to select the fist with the stone). The player unfolded her hands, and if one of the players tapped on the first having a stone, she became player no.1. If she tapped the empty fist, the player who folded her hands became player No. 1. This ruled out the possibility of conflicts of who should take the 1st turn.

Players in Uganda count and play with 1 to 12 stones, known as "ekyokubanza" to "ekikumi nibiri". During the first turn, a player removes some or all the stones from a hole and then adds one back since they are still in the "kyabanza" or first phase. The objective is to place stones on the cleavage and toss one stone up, aiming for it to hold rather than fall (okuribaka). The number of stones pushed out or placed in the hole can be in ascending order, for example, 1 to 12 is the maximum, or in descending order from 12 to 1 stone (ICM-Uganda). In Eswatini, the game of Inketo involves playing with 12 stones. Although the number of stones is not specified in the ChatGPT algorithm, players have the choice to play the stones in either ascending or descending order. Two players begin the game by choosing one stone from a circle, dropping it on the ground or into a hole, and then throwing it. The number of stones inside the circle at the start is 12 (ICM-eSwatini). In South Africa, the Upuca game can begin with any number of stones

There is no limit to the maximum number of stones required to start. However, the more stones there are, the longer it takes to move to the next level...you can take out as many stones as you want from the circle or hole, but you must only retain one stone outside the circle and return the rest. At level 2, the number of stones to keep increases to two, and so on.

In Uganda, the Mdako and Okubaka games are similar in that, when playing with 12 stones, a player throws the ghoen and takes all 12 stones out; then, throws it again and returns 11 stones, keeping one. After that, they throw it again and take out the 11 stones and throw it once more - this time returning nine stones, keeping two. On the fourth throw, they take out the nine stones, and throw it yet again - returning six stones, keeping three. Then, on the fifth throw, they take out the six stones and return two, keeping four. Finally, the sixth step is to throw the ghoen and scoop up the returning two stones, since they are fewer than five and thus should be kept. The indigenous communities confirm the following gameplay pattern:

The Ghoen is tossed in the air, whilst it is in the air then the 10 small pebbles are scooped out of the hole or circle with the same hand before one catch the ghoen. The ghoen is then tossed again in the air and 1 pebble is moved back into the hole or circle simultaneously before catching the ghoen again. This step is repeated until all 10 pebbles are in the hole or circle.

The game becomes more challenging as the levels progress. In Chiyato, a game popular in Zambia, an increased complexity is introduced in the game's final stage.

If a player successfully collects all the stones from the circle without violating any rules, the game progresses to a more challenging stage called Ukubala (spreading). During this stage, the player must scatter the small stones out of the circle of the depression, then gradually return them into the circle according to the stage in which the player is. In stage 2, players would simultaneously place two stones back into the circle while catching the bigger stone before it drops. The remaining stone belongs to the player as a level stone.

The final phase of the Namibian Ondota presents a higher level of complexity, which carries implications for the strategies and planning that must be executed to ensure optimal success in this stage. It is crucial to be mindful of the escalating difficulty of the tasks and to prepare accordingly.

Suppose the player reaches the maximum level, which is level 12. In that case, the player must throw the bigger stone in the air at the same time, pull out all 12 stones and again throw the bigger stone in the air and push them back at the same time, which means it is the end of the game and the winner is determined by the player that reached this stage first.

The game becomes more complicated or simplified based on the size of the circle and the number of stones in play. For example, the smaller the circle, the more challenging it is to bring the small stones back in. Although the size of the circle is determined at the beginning of the game, in a 12-stone game, the size would determine the difficulty level. The game is played until all stones are removed from the circle, if the player follows the rules without making mistakes. Differences in the game mechanics, rules, and complexity are emphasized among the African nations investigated. Players face different problems and possibilities in each variant, which adds to the diversity of IGBL within a social learning environment. These games, rooted in cultural history, provide outlets for community involvement and hands-on education. Players actively contribute to preserving and transmitting traditional knowledge and values, frequently gathering in social settings. The development of problem-solving and critical thinking abilities is fundamental to these games, as players devise and adjust their strategies following the regulations and dynamics of each game. By providing real-time feedback and instruction, ChatGPT's integration as an educational tool enriches this learning process and raises the educational value of these culturally relevant games.

Principle 2: Learn Through Experience - Knowledge in Action

Efficacy

The indigenous communities used the social capital they had from their experiential knowledge of playing the game to analyze the algorithm. The algorithm enabled a comparison of how indigenous communities approached playing the game. A comprehensive examination of the algorithm revealed that the Egyptian Alhasaa (Five Stones) game did not use a circle or hole; instead, it used small stones and included throwing one of the stones up in the air.

Stage 1: Place all five stones on the floor or table. Take one stone and throw it in the air. Pick up another stone from the floor quickly and catch the first one before it falls. Repeat this process until you have all five stones in your hand.

Stage 2: Scatter all five stones across the floor or table. Toss one stone into the air while picking up two stones off the floor. Attempt to catch the first stone before it falls. Repeat this process until you have all five stones in your hand.

Stage 3: Scatter all five stones across the floor or table. Toss one stone into the air while picking up three stones off the floor. Attempt to catch the first stone before it falls. Repeat this process until you have all five stones in your hand.

Stage 4: Scatter all five stones across the floor or table. Toss one stone into the air while picking up four stones from the floor. Attempt to catch the first stone before it falls.

Stage 5: Scatter all four stones across the floor or table. Throw one stone into the air and catch it with the other. Then return it to your original hand and capture all four stones on the floor.

If you drop or fail to catch a stone, you lose your turn, and the stones are passed to the next player. The game is won by the first player to finish all five stages.

Although both Alhasaa and Upuca use small stones and involve tossing and catching the tossed stone before it falls to the ground, the two games are different. Comparing and identifying similarities in indigenous games is a higher-level cognitive activity that develops critical thinking skills. Participants drew on their experience to map out the game's logical flow, giving them a better understanding of what the algorithm was striving to achieve. It was also evident that an effort to modify the algorithm to suit how they understood the game to be played exposed participants to key programming constructs (viz. sequences, loops, and conditional statements) critical for problem-solving (see Table 5).

Table 5:

Exposure to Programming Constructs of Sequence, Loops and Conditional Statements

Basic algorithm for the Upuca game:

1. initialize the game:
 - {minimum of players must be two}
 - Create an empty circle to hold the stones. {(the circle or a hole must not be too big, it must be a size that fit all 12 stones)}
 - {Collect at least 12 small stones and one big stones (we usually use a palm tree nut/seed that we call ondunga)}
 - Put all the 12 small stones in the hole that you created
 - Set the big stone (ondunga aside)}
 - Set the initial level to 1.
 - Set the current player as Player 1.
 - {Set the opponent as player 2}
 - {Set the number of rounds}
 - Set the score of both players to 0.

[Sequence - sets the order of actions to follow before starting to play the game]

2. Start the game loop:
 - {Select randomly who to start first (player 1 or 2 or 3)}

[Selection - determines the path to follow during play]

 - Repeat until the game ends:
 - Display the current level and the current player.
 - Player takes a turn:
 - Player throws the bigger stone (ghoen/ondunga) in the air.
 - Player simultaneously pulls out the stones from the circle.

{If the player did not pull out enough stones for the current level e.g. level 2 you must pull out at least 2 stones or more if not then the player loses on that turn and switches to the next player}

Basic algorithm for the Upuca game:

if successful:}

- Player throws the bigger stone in the air again and the same time pushes the remaining stones back into the circle, {leaving the number of stones that match the level that they are currently in, for example if the player is at level 2 the player must leave 2 stones and it goes on like that for each level}
 - If the player catches the bigger stone successfully:
 - Check if the number of stones collected matches the required number for the current level.
 - If the numbers match, {the player must continue taking out the stones and pushing back the remaining one if they were many and remain with the same current level until all stones are out before moving on to the next level e.g., level 3}
- increase the player's score **{if they completed a level}** and proceed to the next level.
- {- If the numbers don't match, the player's score remains the same, and the level does not change.
 - If the player fails to catch the bigger stone:
 - Switch to the next player without changing the level.
 - Check if the game is over:
 - If the player reaches the maximum level which is level 12, the player must throw the bigger stone in the air at the same time pull out all 12 stones and again throw the bigger stone in the air and push them back at the same time which means is end of the game and the winner is determined by the player who reached this stage first.
 - depending on how many rounds players agreed to go they can start over again with round 2 etc. }

[Iteration - repeat an action depending on the answer, otherwise stop to play, give another player a chance]

3. Determine the winner:

{the player that reached level 12 first and completed it, is the winner

- Compare the scores of both players from each round if it the game was set on rounds}
- The player with the highest score **{from all rounds wins the game.}**
- If there is a tie, declare it as a draw.

[Sequence - sets the order of actions to follow before ending the game]

Principle 3: Research as an Empowering and Transformative Process

Parasocial Interaction

One of the participants (ICM-South Africa) gave an extensive series of comments on the algorithm as follows:

- player 1 toss the ghoen in the air whilst it's in the air, use the same hand to scoop out all the stones before you catch the ghoen.

Adds *the use of the same hand to scoop*, which is one of the rules of the Upuca game.

- player 1 toss the ghoen again in the air then scoop 9 stones into the hole before catching the ghoen. After he/she catches the ghoen, then the stone that remains outside the hole is moved aside.

Player 1 has already kept 1 stone from the first play, which the ICM refers to as “*the stone that reminds outside the hole*”.

- player 1 tosses the ghoen in the air again, retains 2 and returns 7 stones into the hole/circle before catching the ghoen.

This ICM elaborates, the number of stones left behind in each level is according to the level, which is 1 stone, level 2 two stones, level 3 three stones etc.

- the above process is repeated with just 1 stone being removed each time until there are no more stones left to move back in the circle. The player then tosses the ghoen in the air then pat on the floor with the palm of his hand next to the hole before catching the ghoen again.

A further addition needed in the algorithm is how the end of a level is marked. Once a player has successfully played the round, the ghoen is tossed in the air, pats with the palm of their hand and catches the ghoen. They then proceed to the next round.

- Then, the player moves to level 2, and all 10 stones are moved back in the circle. Starting the entire process as in level one but this time 2 stones are left behind each time the stones are scooped /moved back in the hole/circle.

There is also a difference when playing with odd numbers of levels.

- If there is an uneven number such as in level 3 then the remaining stone is moved last. And each level always starts with the 10 stones in the hole.

At the start of each level, the game is initialized to the starting number of stones. A player will continue the level they were in before they lost a turn.

- Each time the players start from the level they previously left off and the person who completes the tenth level first with the least mistakes wins.

A winner can also be declared if they have reached the highest level compared to other players in the same game.

Another critique of the algorithm was conducted to ensure that the algorithm adequately reflected the way the game is played in Namibia. This review highlighted the need for revisions, which the indigenous community helped to identify. As a result of their insights, the following modifications were suggested: If the player did not remove enough stones for the current level (e.g., level 2), they must pull out at least 2 stones or more. If not, then the player loses on that turn and the next player continues. If successful, the player throws the bigger stone in the air again and simultaneously pushes the remaining stones back into the circle, leaving the number of stones matching the level they are currently in. For example, if the player is at level 2, they must leave 2 stones, and it continues like that for each level. If the player catches the bigger stone successfully, check if the number of stones collected matches the required number for the current level.

- If the numbers match, the player must continue taking out the stones and pushing back the remaining one if there are many and remain with the same current level until all stones are out before moving on to the next level e.g., level 3.

Considering changes that would align the algorithm with how the game is played in Zambia, the following suggestions were made:

First, place all the smaller stones in the circle. Then, throw the larger stone into the air and sweep as many smaller stones out of the circle as possible before catching the larger stone. Next, throw the larger stone again and sweep all but one of the stones back into the circle. Keep this rock in front of you and continue this process until all the small stones are in front of you. If you fail to catch the larger stone or leave more than one stone outside the circle, you will pass the turn to the next person to have a go.

Another suggested modification to the algorithm was as follows:

If a circle instead of a hole is drawn [usually using charcoal], another rule sets in, the player loses if in the process of throwing the big stone in the air and either removing or pushing the stone(s) back into the circle a stone(s) remains on the circle line, or escapes outside the circle or hole.

The ICM in Uganda proposed modifying the algorithm to determine a winner. The modification aims to ensure the accuracy and effectiveness of the algorithm, thus ensuring the fairest possible outcome.

The winner was one who successfully threw the big stone in the air and never missed catching it as she removed or placed stones in the hole, one whose stones never missed the hole/circle, one who was able to remove/place back into the whole the correct number of stones (with and without them going through the thumb and 1st finger, one who was careful to ensure that neither the stones outside the hole shook each other, nor her hands accidentally touched another stone, etc..

By incorporating suggestions from various ICMs, the algorithm captures the essence of Upuca as it is experienced in diverse cultural contexts increasingly accurately. This series of enhancements fosters authenticity and inclusivity in IGBL. Additionally, it enhances the algorithm's adaptability and ability to accommodate different types of games. It addresses issues like the lack of varying difficulty levels, fixed rules for manipulating stones, and constrained gameplay dynamics.

Principle 4: Collaboration Through Dialogue

Participant Reflections

Participants were asked to reflect on their learning experience of analyzing the ChatGPT algorithm of a familiar indigenous game. Observations suggested that participants acquired computational thinking skills.

Break down a complex problem of a game into smaller parts

“Breaking the games into smaller parts helps one to think about the details of the games which include safety features such as smooth stones when using stones to play if one does not have pebbles.”

A problem-solving skill may have been acquired:

Taught me to do things in stages from simple to complex, from known to unknown, ichiyenga (Zambian dialect) was said to be a very difficult game, but once it's being played, players would not realize that they have even gotten through to a more challenging stage. This is because it was broken down into small components.

In general, indigenous games are not written down. One participant observes the effect of reading a written algorithm of an indigenous game and what it does to cognitive abilities.

Experience on the steps on how the game is played and writing down the steps helps with improving memory as one needs to stretch and try to think far back on how it was exactly played and the rules involved, it also helps with improving one's ability to organize one's thoughts and the information.

Identifying common features of a game played in other countries

One participant observed that algorithm analysis removed ambiguity and improved clarity in comparing games, “Had to move through all the steps to identify the similarities and differences in the games.

Participants were able to identify patterns in the logic of a game to the extent that they could recognize ways of improving an algorithm, which suggests that computational thinking skills may have been acquired.

Mostly when I am going through a game played in my own country Zambia, and I find another similar game in another country. I go stage by stage to see differences and similarities. These comparisons go beyond the game and into cultural comparisons and values. In a culture where they value equality, most games end in a draw, otherwise it's win or lose.

Another participant could see how the thinking involved in the algorithm of the Upuca game could be used in analyzing other games; this suggests computational thinking skills may have been acquired.

Noticing the patterns of how other games were played made it simpler for me to follow the same pattern of thinking to try and follow the same pattern of writing down the steps of the games I played as a child. It was easy to follow through the steps of playing these games to identify the differences and similarities. If there was a difference in perspective on how the game was played and the requirements of what was required to play the game, then I could easily indicate what needed to be added.

Using prior knowledge of the game was critical in helping participants analyze the ChatGPT algorithm.

Understanding the underlying logic of how the game is played in South Africa and having an experience of how the game is played one can understand how the game is played in other parts of Africa and can then apply those games to other cultural backgrounds, as I was able to identify the pattern of the steps.

Understanding the Set of Steps Required to Play the Game

One participant commented on the observation and analytical skills needed when analyzing an algorithm.

Starting up with 12 stones and filtering them through a game with all the stones played out of the circle would keep the mind sharp and alert as well as promote good observation and analytical skills for the players. Additionally, the approach would help in solving mathematical problems which entail strategies for quick additions and subtractions within pedagogical spaces.

Commenting on how different the Egyptian Althasaa is compared to the South African Upuca, one participant believed that the dialect played in Egypt could have 'travelled' from South Africa with adaptations on the way.

When I looked at others' explanations of the versions of games played like Dibeko, I had to look at the steps to identify the differences or similarities between the games. It makes me wonder how these games really filtered down through Africa. Were these games passed on through different people from different cultures whilst travelling and somehow some aspects of the

games were not captured or was there an addition to the game steps as a spontaneous way of making the games more interesting?

One participant concedes that both logical reasoning skills and problem-solving skills were involved in identifying the different patterns or steps in the algorithm analysis.

By being able to identify the differences and similarities in the games by looking at the different steps of how to play the games, it requires one to recognize the patterns, use logical reasoning skills and problem-solving skills by identifying the different patterns or steps in play and then deciding. It develops algorithmic thinking and creativity to be able to break down the complex games into steps on how to play.

Gaining clarity in understanding a game

One of the benefits of using an algorithm is that it provides a logical map of how the game is played, which is a precursor to programming.

I think that drawings or pictures, if possible, should be included to show how the games are played as well, I think that it is much easier for me to understand how the difference of the games are played as I have experience of playing the Dibeko game and five stones here in SA.

One participant observed the process and how this engages the mind to think about steps involved in playing the game.

If I played the game, at that time it went to automated play without even looking at the details involved, now I go to details of what makes sense and what doesn't. Making sense out of a game gives rise to the steps involved and the details.

It could be seen that the computational skills developed using indigenous games could be transferable to other contexts:

The breakdown of the steps in games such as Dibeko and five stones helped me with trying to explain the steps of the games in a similar way. My experience and basic understanding of how to play these games as a child allow me to have a clearer picture of how to play similar games in Africa with different explanations.

DISCUSSION - COMPUTATIONAL THINKING SKILLS

In this discussion, an evaluation of the acquisition of computational thinking skills is presented under the headings: acquisition of the ability to break down a complex game problem into more manageable components; filtering how one played or did not play a game in their country; and understanding a set of steps required to play and win the game.

- i. Acquisition of the ability to break down a complex game problem into more manageable components

One participant learned to identify logical patterns in algorithms, which facilitated the acquisition of computational thinking skills. "Recognizing the patterns in how other games were played made it easier for me to adopt a similar approach to thinking and to articulate the steps of the games I played in childhood" Another individual reported learning to deconstruct the steps involved in playing the game, "The deconstruction of the steps outlined by others in games such as Dibeko and five stones assisted me in explaining the game's steps in a similar manner... similar games played in Africa, but with different explanations... breaking down the games into smaller parts forces one to consider specific game details, including safety measures such as smooth stones for use when pebbles are unavailable." The use of

familiar and meaningful indigenous games facilitated a relatively smooth transition from simple to complex, enabling the swift establishment of foundational computational skills, as suggested by the following statement: "It taught me to approach tasks in a staged manner, progressing from simple to complex and from known to unknown... players might not even realize that they have advanced to a more challenging stage, as it has been broken down into small components." This is consistent with Tedre et al.'s (2006) idea of ethnocomputing being "local systems of computational knowledge, starting from its very basic ideas and advancing to more sophisticated concepts". The analysis of algorithms provides an effective way to compare features of games played in other countries. This is evident from the following comments: "It was interesting to see how the game of five stones in Egypt ended with a level 5, which now makes more sense to me as an adult. In South Africa, our game should end similarly, with a change of hands. This is because the game allows for hand-eye coordination, but when the hands are swapped while throwing the stone in the air and catching it with the other hand, it creates a certain alignment. This indicates that the game has concluded, aligning more with the process of completing levels in Diketo." Another participant observed that they "go stage by stage to see differences and similarities. These comparisons go beyond the game and into cultural comparisons and values."

Interpretation: Social learning - [modelling (behavior with respect to recognition of logical patterns to see differences and similarities is too complex to be elucidated without demonstration or illustration)].

- ii. Filtering how one played or did not play a game in one's home country

There is a need to apply computational thinking to construct algorithms for indigenous games based on the dialects. This provides useful opportunities for teaching computational thinking, as evidenced by the following comment: "it makes me wonder how these games really filtered down through Africa. Were these games passed on through different people from different cultures while travelling, and somehow, some aspects of the games were not captured, or was there an addition to the game steps as a spontaneous way of making the games more interesting?"

Interpretation: Efficacy - [needed to leverage social capital i.e., games passed on through different people from different cultures culminate in dialects that enrich analysis of the algorithm]

- iii) Understanding the set of steps required to play and win the game and gaining clarity in understanding how a game aligns with how the evaluators recall having played it

In view of the variations in the dialects of the games, the need for visual representation to aid computational thinking was suggested:

"I think that drawings or pictures, if possible, should be included to show how the games are played as well. I find it much easier to understand the differences in how the games are played, as I have experience playing the Dibeko game and five stones here in South Africa. When visualizing how the games were played as a child, one taps into imagination, and it makes me think that visual pictures or drawings should be included to explain how the games are really played as well."

One of the computational thinking skills acquired was the portability of analytical skills from one game to another, as aptly summarized by a participant: "If I played the game, at that time it went to automated play without even looking at the details involved. Making sense out of a game gives rise to the steps involved and the details."

Interpretation: Parasocial interactions - [transferable and practical knowledge e.g., visual pictures or drawings should be included to explain how the games are really played. This fosters acquisition of skills that can be applied to other contexts]

Participants acquired the following skills: an ability to break down a complex game problem into more manageable components; the ability to recognize how one had played or did not play a game in their home country; and an ability to understand the set of steps required to play and win the game. These computational thinking skills, as Wing (2006) notes, are crucial skills that enable individuals to address challenges and develop systems beyond their capabilities. Further research is required to develop differentiated computational skills acquisition models based on learning various types of indigenous games by players from different age groups.

CONCLUSION

Through its focus on culture and computing, this ethno-computing paper challenges what Yadav and Berthelsen (2021) refer to as the reproduction of the colonial logic of assimilation and extraction in education. It has been demonstrated that there is a strong connection between ethno-computing, indigenous games, and computational thinking. The indigenous communities did not acquire computational thinking skills, but instead applied their existing computational skills (gained from playing indigenous games) to challenge Western algorithms generated by ChatGPT. The indigenous communities' explanation of logical sequencing showed that three programming principles of sequence influenced the extent to which indigenous communities demonstrated such skills. These are demonstrated as firstly, the order of instructions needed to play the game; secondly, what needed to happen for a player to pass their turn to the next player and the fact that a player can keep playing until they make a mistake; thirdly, how the game is concluded and how a winner is declared. Therefore, they possessed computational thinking and problem-solving skills, which can be transferred to the analysis of other indigenous games. The paper has revealed that developing an algorithm for an indigenous game can be challenging. To address this obstacle, ChatGPT modelled algorithms for well-known indigenous games. This was a crucial factor as it ensured that the required social capital was present for the research, sustaining an entertaining and meaningful activity. Furthermore, the study highlighted the usefulness of ChatGPT as an educational tool. One of the outcomes of the study was that it acknowledged the role of ChatGPT in a social learning process, specifically its capacity to craft algorithms for different dialects of an indigenous game and to demonstrate its efficacy as a tool for imparting computational knowledge to indigenous communities.

Integrating the suggestions of the ICMs improved the algorithm’s adaptability. Also, it allowed regional peculiarities specific to each African country to be included, ensuring that the game will be inclusive and culturally relevant. This algorithm serves as a framework that can be easily adjusted to implement IGBL programs, and this in turn helps preserve cultural heritage and fosters the growth of computational thinking skills in various African cultural contexts.

The ChatGPT-mediated analysis presented includes the social learning of indigenous games, application of algorithms, and computational skills acquired. These are summarized in Table 6.

Table 6:

ChatGPT Mediated Analysis of Indigenous Game for Computational Thinking Skills

Social learning	Application	Acquired skills	Comments
Principle 1: Leverage experience of participants	Indigenous game dialect ChatGPT algorithm	Skill to recognize an indigenous game as a computational thinking activity	Namibia (Ondota), Zimbabwe (Nhodo), South Africa (Diketo Upuca), Lesotho (Magave), eSwatini (Inketo), Zambia (Chiyato Ichiyenga),

Social learning	Application	Acquired skills	Comments
[Modelling] (Behavior is too complex to be elucidated without demonstration or illustrations)	Google Classroom engagement		Mozambique (Mathocosana Mathakuzana), Kenya (Mdako), Uganda (Mdako), Egypt (Alhasaa Alal) and Cameroon (Seven Seven)
Principle 2: Learn through experience [Efficacy] (Requisite social capital for analyzing the algorithm)	Reading a written algorithm of an indigenous game Algorithm offered a clear language for understanding the logic of the game	Skill to break down a complex problem of an indigenous game into smaller understandable parts Skill to understand a set of steps required to play the game as like steps in any problem-solving situation	Reliance on prior knowledge of the game to analyze an algorithm was effective in fostering acquisition of problem-solving skills
Principle 3: Research as an empowering and transformative process [Parasocial interactions]	Reduced ambiguity and improved clarity in comparing games Recognizing ways of improving an algorithm	Skill to identify and compare indigenous game's logical features	Computational thinking skill may have been acquired
Principle 4: Collaboration through dialogue (Transferable knowledge acquired that can be applied to other contexts)	Confidence to apply reasoning to analyze other games		

Note. This table summarizes the computational thinking skills acquired when participants used their prior knowledge of an indigenous game to analyze a ChatGPT generated algorithm.

The paper concludes that PAR's four principles guided the acquisition of computational thinking skills as follows: Principle 1: Leverage experience of participants; Principle 2: Learn through experience - knowledge in action; Principle 3: Research as an empowering and transformative process; and Principle 4: Collaboration through dialogue. The application of Bandura's Social Learning Theory provided a framework for articulating the computational thinking skills developed through participatory action learning from a ChatGPT-generated algorithm of indigenous games. These principles can be conceptualized as: social learning, efficacy and parasocial interactions. The participants demonstrated the skill to recognize an indigenous game as a computational thinking activity, to break down the complex problem of an indigenous game into smaller understandable parts, to understand the set of steps

required to play the game as being like steps in any problem-solving situation and to identify and compare the indigenous game's logical features.

INFORMED CONSENT STATEMENT

The project obtained ethical clearance from the University of Cape Town's School of Education. In alignment with the principles of Participatory Action Research (PAR), collaborators were integral members of the project.

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CONFLICTS OF INTEREST

There is no conflict of interest for authors.

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