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The Place of Indigenous Cultural Games by Educators in the Teaching and Learning of Mathematics

Charity Dewah and Micheal M. Van Wyk

[1]National University of Science and Technology, Bulawayo, Zimbabwe
E-mail: charitydewah@yahoo.co.uk
[2]Department of Curriculum and Instructional Studies, College of Education, University of South Africa, South Africa
E-mail: vwykmm@unisa.ac.za

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ABSTRACT Many human activities have some mathematical ideas embedded in them. The use of indigenous games is one way of giving context that can help students enjoy and understand mathematics in order to apply it in their everyday lives. The paper gives an empirical assessment of the game of pada that is played by many indigenous children in Zimbabwe. The purpose of the study was to explore mathematical ideas that are embedded in the game of pada. Five children from Gweru urban participated in the study. Focus group interviews and observations were used to gather data and inductive analysis was then used to analyze the data. The study revealed that ideas of counting, inverse variation, geometrical constructions, projectiles, statistics, permutations, combinations and angles of elevation and depression are embedded in the game of pada. The study recommends the training of teachers to utilize indigenous knowledge systems and local cultural games when teaching mathematics in order to fight methophobia among African students.

INTRODUCTION

All people engage in a variety of activities in their everyday life depending on the culture of their particular area. In Zimbabwe there is a diversity of cultures and people of a particular culture have their own ways of looking at and relating to the world and to each other. People use ideas of mathematics in their daily activities though they may not be aware of it. The mathematical knowledge is stored in people's memories and activities are expressed in stories, puzzles, riddles, folklore and games (Grenier 1998). The mathematical knowledge that people have outside the formal school system can be made use of in the teaching and learning of school mathematics. Barnhardt and Kawagley (2005) are of the view that "the culture and knowledge systems of people and their institutions provide useful frameworks, ideas, guiding principles, procedures and practices that can serve as a foundation for the teaching of school mathematics".

Games are an aspect of culture and are played by both adults and children in Zimbabwe and the world over. Indigenous games are an integral component of indigenous knowledge systems (Kazima 2013; Mosimege 2003). These and other games in general are usually viewed from the narrow perspective of play, enjoyment and recreation. Even though these are important, there is more to games than just the aesthetic aspects. Masiwa (2001) stated that many mathematical ideas could be traced to some of these games. However, children do not think about the mathematics involved in the games that they play and in many other daily activities they are involved in. It is the mathematics teacher's task to make use of those daily activities of children to provide them with numerous opportunities that would enable children to make valuable links with their prior knowledge. This would facilitate meaningful learning of mathematics since new knowledge would be built on the children's everyday experiences.

In Zimbabwe it is not only students in schools who have a dislike of mathematics. Some adults who look back on their days at school remember mathematics as the subject which they found the most difficult. Even teachers who have to choose a main subject at primary school teachers' colleges seldom choose mathematics. This was also noted by Willoughby (1990), who remarked that large numbers of people who have been taught some mathematics have the general belief that "mathematics is akin to mysticism-formulas and procedures handed down to be memorized and used when necessary, but never to be understood by mere mortals". Moreover Zaslavsky (1973) as well as Kazima (2013) also acknowledged that children tend to view mathematics as a "cut-and-dried, esoteric subject that arose full-blown from the minds of the white men in the past". For example, in Zimbabwe many students have just developed negative attitudes towards the subject maybe because no one in their family had passed it hence consider their failure as being hereditary. It should be no surprise that many students find mathematics irrelevant, develop fears and anxiety about the subject and want to drop it as soon as possible. This general lack of confidence normally indicates that people were taught mathematics in the wrong way yet mathematical issues cannot be separated from real life activities and experiences.

Evidence is there that many countries are worried about the poor performance of most students in mathematics and Zimbabwe is not an exception. Researchers have tried to find the answer to this phenomenon, and changes have been made to approaches in mathematics and to teacher training yet the solution to the problem seem elusive (Kazima 2013). From the researcher's observation the reason may be that the teaching of mathematics in Zimbabwean schools is done without teachers taking in to account the students' prior mathematical knowledge. The teaching of mathematics is often formalized into intellectual units that have no relationship to the child's daily experiences and interests. Several scholars acknowledged that classroom activities are too exclusively abstract, remote and essentially divorced from the children's experiences and purposes that might make them relevant and meaningful (Kazima 2013; Rosa and Orey 2011). The ultimate result is general disinterest in mathematics. This was also supported by Gilmer (1990) who opined that one of the reasons for the students' poor performances in mathematics is that goals, contents and methods of mathematics education are not sufficiently adapted to the cultures and needs of the African people. Mathematics instruction should move away from the information transmission model whereby the teacher is the supplier and the pupils are the passive recipients of mathematical knowledge and skills. Mathematics should be shifted to an engaging activity where students become active participants in the learning process and the use of games in the teaching and learning of mathematics is one way of involving learners.

Many researchers have found that using games can make mathematics classes very enjoyable, exciting and interesting (Kazima 2013; Troutman et al. 2008; Willoughby 1990). Games in mathematics provide opportunities for students to be actively involved in learning. They allow students to experience success and satisfaction, thereby building their enthusiasm and self-confidence. Games also help students to understand mathematical ideas, develop mathematical skills and know mathematical facts. Games that involve number or strategy stimulate children's mathematical imagination and thinking. Developmental psychologists and mathematics educators have noted that children are intellectually motivated to learn through games and other thinking activities (Knight 2003). When children feel appropriately challenged by a game they become intrinsically motivated to discover the secret of winning or of avoiding a loss. The sheer pleasure of playing a particular game enables children to learn mathematical ideas embedded in it as a by-product of playing (Kazima 2013; Troutman et al. 2008). Moreover, by actively observing and carefully listening to children as they play, teachers can learn about how children think and the mathematical ideas that they are constructing.

Research has shown that the ability to listen and understand (concentration) and to display keen observation techniques is frequently absent among children (Knight 2003). This also affects the children as they advance to higher mathematical levels. The use of games in the teaching and learning of mathematics can help alleviate such problems. Positive attitudes and skills can be honed and practiced through fun games. The games that children play offer a natural model for an integrated approach to mathematics. Children are exposed to mathematical concepts as well as patterns of social behavior that help them to co-operate and relate to each other. Willoughby (1990) insists that games offer excellent problem-solving opportunities. There is increasing evidence that games are an aid to the teaching and learning of school mathematics (Gilmer 1990).

Bishop (1991) is of the view that education cannot be truly effective unless it is intelligently based on the indigenous culture and living interests. Games that children play are part of their culture and there are other various activities besides games which children may engage in their daily lives which also have mathematical ideas embedded in them. It is therefore important for teachers to understand the cultural background of the pupil and then relate the teaching of school mathematics to it. Knight (2003) noted that very poor children already acquired skills in spending money and giving correct change before they actually enter the formal school system. The reason is that they start engaging in buying and selling before they go to school in order to help their parents to find food and clothes. Rich children also acquire the skills because they are given money to buy what they want at early ages because their parents can afford it. So both groups of children acquire mathematical ideas from different situations that they are in. Other researchers also noted the existence of out-of-school mathematics, mathematics that is not necessarily learnt in school (Gilmer 1990; Carraher 1991; Mosimege 2012). According to Carraher (1991) that mathematics exist out-of-school is shown by the fact that children develop understanding of numbers before they come to school. Boaler (2000) also conducted studies of street vendors and found that the mathematics, which they use, can provide a very strong support for effective performance in the learning of school mathematics. Often the performance undertaken in this context does not resemble the formal mathematics of the school. However the mathematical ideas can be used effectively in the teaching of school mathematics.

Research shows that mathematical ideas exist in all cultures around the world, but their emphasis, expression and context varies from culture to culture. Some examples of traditional mathematics of Australian Aborigines include counting in non-decimal systems, recognition of patterns in relationships between clans and calendars based on natural changes in the environment. All these researches are done in a bid to improve the teaching and learning of school mathematics. It is hoped that approaches in the teaching and learning of school mathematics, which take into account the cultural context and the mathematical systems in use within the community are likely to be more effective.

Studies on the mathematical ideas in riddles and story puzzles were also conducted in Africa. Ascher (1990) analyzed the mathematical-logical aspects of story puzzles from Algeria, Cape Verde Islands, Ethiopia, Liberia, Zambia and Tanzania. Riddles and puzzles enable students to develop mathematical thinking skills. Furthermore, Ascher (1990) also made a detailed study of a game of *mu torere* that is played in New Zealand, and identified mathematical ideas embedded in it. Ascher (1991) gives examples from different cultures which, include Bushong sand figures and Malekula sand tracing which illustrate graph theory, Inca strip patterns and Maori rafter patterns-geometry, Iroquoi games-chance and Maori games-strategy. All these studies support D'Ambrosio's (1985) view that outside school almost all children in the world become matherate, that is, they develop the capacity to use numbers, quantities, the capability to qualify and quantify and some patterns of inference.

Critics of the use of the learner's culture in the teaching and learning of school mathematics argue that many educators are unfamiliar with the links between mathematics and the surrounding world. Many teachers do not have time to research and employ strategies aimed at aiding all ethnicities of students in their classrooms. For example in Zimbabwe teachers have heavy loads and at the same time they need to complete syllabi so that they have enough time to prepare their students for examinations. Their teaching is examination centered such that they would view carrying out research on their student's backgrounds as mere waste of time. Culturally relevant mathematics instruction presents new challenges for teachers and teacher educators. Building on children's informal mathematics knowledge will require going beyond a view of mathematics as a decontextualised and sequenced set of skills that students need to memorize and toward asking questions about and valuing how children use mathematics in their everyday lives. If games are to be used effectively in the teaching of mathematics there is need for proper planning so that the lesson objectives will be achieved. Mathematics lessons that utilize various traditional games can be important vehicles through which mathematics concepts can be taught while showing respect for different cultures (Troutman et al. 2008; D'Ambrosio 2001; Zaslavsky 1993; Gilmer 1990).

Statement of the Problem

Indigenous games that are played by children are an aspect of their culture. A close analysis of these games reveals some mathematical ideas that are hidden in them. Thus the problem is to explore mathematical ideas embedded in the game of pada.

The objective of the study was to examine and identify the mathematics in the game of pada.

Research Questions

The following specific research questions are addressed:

1. How is the game of pada played?
2. What mathematical ideas are embedded in the game of pada?

METHODOLOGY

Focus group interviews and observations were used to gather data. Five children from Gweru urban participated in the study. This study used qualitative enquiry, which is both analytic and interpretative. An in depth study of the activities involved in the playing of pada was made in order to identify the mathematical ideas embedded in the game. The researcher observed the children playing the game over eight consecutive days. Qualitative research involved examination, analysis and interpretation of observations for the purpose of discovering underlying meanings and patterns of relationships. The data gathered was mainly descriptive of the activities involved in the game.

FINDINGS

Mathematical Ideas in the Arrangement of Players

Permutations

Not more than four players play the game. This is a game rule and it enables the game to be manageable. If there are too many players they may have problems in remembering the box in which a player will have ended because the children do not record anywhere but they rely on their memory. So, if four players are playing the game, there are 4 ways of choosing the first player. After choosing the first player, there are three players from which to choose the second player. Thus for each of the 4 ways of choosing the first player there are three ways of choosing the second player. Hence there are 4x3 ways of choosing the first two players. The third player can be chosen from the remaining two players, so for each of the 4x3 ways of choosing the first two players, that is the first player and the second player, there are two ways of choosing the third player. That is there are 4x3x2 ways of choosing the first, second and third players. For each of the 4x3x2 ways of choosing the first three players there is only one possibility for the fourth player. Hence there are 4x3x2x1 ways of arranging the four players. So if there are *n* players generally the number of ways of arranging the players is nxn-1xn-2xn-3x….x2x1.

Combinations

Now regardless of the order in which the players are arranged, the identified group of permutations is just one choice, which is called a combination.

Probability

By choosing to be the first one to play the game, children said that there were more chances of winning the game. All the boxes will be exposed to the first player, thus there would be high chances of winning. Assuming that the probability of the pebble to land in any one of the boxes is the same, the first player would have 8 boxes at his or her disposal so there will be 8/8 chances of winning. If the first player wins a box then the second player will have 7/8 chances. Thus the chances for the other players will be less by the number of territories won by the preceding players. However, this may not be true since the first player may fail to win a territory hence the story will be different.

The children showed that they have the concept when they talked about high chances, though they were not using the technical term. This confirms Zaslavsky's (1973) and Troutman et al. (2008) opinion that students have an idea about a lot of mathematics, however they lack the terminology.

Experimental Probability

As the children played the game the researcher observed and recorded the number of times the player in the first, second, third and fourth position won the game. Ten games were considered. The results were as given as in Table 1.

Table 1: Experimental probability

Position of player	*First*	*Second*	*Third*	*Fourth*
Number of games won	5	3	1	1
Probability	5/10	3/10	1/10	1/10

The results show that there are more chances of winning if one plays first. The third and fourth players have lower chances because most of the boxes would have been occupied by the first and second players. Also if the first 4 or 5 boxes have been won by the first or second player(s) it becomes difficult for the next player to skip all the won boxes without losing balance. Assuming that the probability of winning any one box is the same for all the boxes, the probability that the first player wins a box is 1, that is 8/8 because he/she has all the 8 boxes at his/her disposal. If one box is won the probability of winning a second box is 7/8. This shows that the first player has high chances of winning the game.

The Playing Field

One of the children would draw the Figure 1 on the ground as shown below:

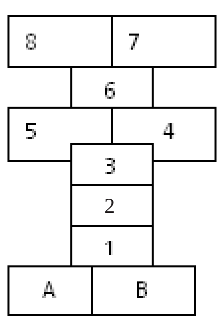

Fig. 1. The playing field

The playing field consists of ten rectangular boxes. However there are many variations of the diagram used throughout the world. In some countries the diagram consists of a combination of rectangles and circles while in others it consists of a large square divided into 6 or 9 small squares. Even the names of the game vary from one country to another, for example, in Zimbabwe it is called pada, in Colombia it is known as rayuela but the diagram is the same as the one shown above. In Indonesia it is called one-leg jump. The researcher is of the opinion that the children chose rectangles which seem to provide more space for the pebble to land in. This shows that the children have some form of understanding of geometric space.

Mathematical Ideas in the Structure of the Playing Field

Counting: Children learn to count using the diagram for the game. When the player throws the pebble in box1 they say "mamu" 1 and when in box2 they say "mamu" 2 up to "mamu" 8. They can also count the number of boxes that one has acquired as territories so as to identify the player with the highest number of territories and will be the champion of the game.

Geometrical Construction*:* Children can learn about rectangles from the structure of the playing field. They can learn about properties of rectangles such as the number of sides and their sizes, diagonals, number of angles and their sizes, sum of the angles, lines of symmetry and also the idea of parallel lines.

Mathematical Ideas in the Playing of the Game

Inverse Variation

The more the number of players, the less the number of boxes to be won as territories by each player. The number of boxes won by a player as his/her territories varies inversely with the number of players.

Let N be the number of players and n be the number of boxes. Thus $n \alpha 1/N$ meaning that $n = k/N$ where k is a constant of proportionality. The given playing field is the standard one and also the number of players being not more than 4 is the one considered to be manageable. If the number of boxes and the number of players can be increased then there will be the idea of *direct variation.*

Projectiles

The pebble, which is thrown, is a projectile. One can consider the flight of the pebble from the moment it leaves the player's hand until it gets into a box, either in the initial stage of the game or the winning stage of the game where a player would throw it to win a territory. Throughout the flight the only force acting on the pebble is its own weight so its acceleration is *g* vertically downwards. For the pebble to get into the targeted box the initial velocity and the angle of projection are important. Thus the distance moved by the pebble from the point of projection to the targeted box depends on the initial velocity, and the angle of projection. The greater the projection speed, the greater the range. The projection speed is high at a low projection angle.

Thus by squatting, the player will be trying to reduce the height of projectile release and hence ends up reducing the angle of projection which in turn increases the projection speed and ultimately the range. So when the player is targeting boxes that are further away from the starting point, he or she tries to make the angle of projection as small as possible depending on the distance to be covered by the projectile.

The assumption made here is that only the force of gravity acts on the vertical motion of the pebble and no frictional forces impede the horizontal motion. When the pebble is released it leaves with a specific velocity. Being a vector quantity, the velocity has both magnitude and direction. The projected speed is *v* and the angle is θ. The velocity has both horizontal and vertical components. The horizontal component of the velocity is given by $v_h = v\cos\theta$ and the vertical component is given by $v_v = v\sin\theta$. The vertical velocity changes as the pebble accelerates towards the ground. The range is given by $R = v^2\sin2\theta/g$. The range increases with increasing angle of projection for $0<\theta<45^0$. The maximum range occurs when the value of $v^2\sin2\theta/g$ is greatest. This occurs when $\sin2\theta = 1$ that is when $\theta = 450$. Thus the maximum horizontal range is given by v^2/g. The range decreases with increasing angle of projection for $450<\theta<90^0$. Sin20 is thus an increasing function for $0<\theta<45^0$ and decreasing function for $45<\theta<90^0$.

Statistics

To aid their memory the children can make a tally chart where they would write the names of players and record against each name when the player wins a game. For example in Figure 2 if there are players P, Q, R and S, the tally chart would be as follows:

The children would learn the tallying system by using this recording system. The idea of frequency would also come out as they count the number of tallies for each player to find the number of games won by each of the players and hence use the frequencies to determine the winner. In using frequencies to find the winner the idea of *mode* is evident, that is, the player who won the highest number of games. In this example it would be P who won 5 games. The *mean* number of games won can be calculated from the table. Mean = (5+3+1+1)/4=2.5. So if there are *n* players the mean number of games would be the sum of number of games won by players divided by n. If the number of games won are arranged in order of size the median number of games won can be found.

Using the information from the table some *bar charts* can be drawn. The information can also be shown on a pie chart. The angles of sectors representing the number of games won by each player can be calculated. For example, P won 5 games, so the angle of sector would be $5/10 \times 360^0 = 180^0$. For Q the angle would be $3/10 \times 360 = 108$. R and S would have $1/10 \times 360 = 36^0$ each. Generally if the total number of games played was *N* and a player won n games then the angle of the sector would be $n/N \times 360^0$.

Angles of Depression and Elevation

As the player tried to target a box he or she had to lower his/her line of sight from the horizontal through an angle *d*. The angle *d* is called

Player's name	P	Q	R	S
Games won	𝍸	III	I	I
frequency	5	3	1	1

Fig. 2. The frequency game

an angle of depression. The size of the angle of depression depended on the distance of the targeted box from the starting point, that is, boxes A and B. The closer the box to the starting point the greater the size of angle *d*, the angle of depression. When the player raised his/her line of sight back to the horizontal an angle of elevation *e* was noted. The angle is also affected by height. The greater the height, the smaller the angle of depression and results in the pebble landing in boxes closer to the starting point. $d=e$ (alternate angles). The relationship between the height *h*, the distance travelled by the pebble, *s*, and the angle of elevation e is an aspect of trigonometry and is given by tan e= h/s.

Winning Strategies

The goal is to win as many boxes as possible as one's territories. When playing the game a player would look for a pebble that would not move after landing in a particular box. The player would gauge the initial velocity with which to release the pebble so that it would land in to the targeted box. In some cases a player would squat trying to reduce height thereby increasing the distance travelled by the pebble if it had to land in boxes far away from boxes A and B say boxes 6,7 and 8. The release height and the release velocity are inversely proportional, that is, $v \propto 1/h$. So if the height is reduced the velocity is increased thereby increasing the distance travelled by the pebble.

When throwing a pebble to win a territory there is an aspect of estimation. The player needs to estimate the distance of the targeted box from the starting point. He/she goes on to estimate the velocity at which the pebble can be released. If the player targets boxes further away from the starting point the pebble is released with more velocity than when boxes closer to the starting point are targeted. Thus in this case the distance travelled by the pebble is directly proportional to the velocity with which the pebble is released. So if s is the distance and v is the velocity then $s \propto v$.

There is also the idea of *spatial sense* whereby the players need to understand the relationships between the position of boxes and the starting point. They need to estimate the size of the boxes and the direction in which the pebble is to be thrown.

In the early stages of the game when the player will be aiming a box there is need for the player to have very good eye-hand coordination. The player's eyes will be fixed to the box that he/she is aiming and the hand holding the pebble needs to coordinate well the eyes for the pebble to land in the targeted box.

Social Behavior

The game of pada teaches children to concentrate in whatever they are doing and this can also help them even in their mathematics lessons. They also learn to follow instructions since in the game there are steps to be followed until one wins the game and mathematical activities are full of instructions. For example, when solving equations with fractions, a learner is told to find the lowest common multiple of the denominators. Then multiply both sides by that common multiple to clear fractions. The next step is to collect like terms and simplify where possible. The final stage is to divide both sides by the coefficient of the unknown thus getting the solution. There is a lot of endurance since one would play again and again until one wins a territory. This also teaches a child to work on a mathematical problem until a solution is obtained. In society everyone wants to own properties. The children get satisfaction by owning a number of boxes as their territories, thus the game also teaches them about ownership hence in life they will try to work hard to get something to be proud of. The game is an individual game in which each player fights alone to win.

DISUCSSION

From the research results it was discovered that the concept of *counting* was embedded in the game of pada. Teachers can make use of these results in the teaching and learning of mathematics during the early years of primary school mathematics. This can enable children make connections between the formalized ways of counting and their everyday life. Children generally enjoy playing so in the process of playing they can also learn how to count. This also teaches the learners to pay attention since in playing the game they need to be very alert and also need to concentrate on what they are doing so that no cheating occurs.

The idea of *properties of rectangles* is also found in the game. Children learn about shapes from what they already know and this would help them to understand the concept better.

Permutations and combinations were also identified. These concepts are taught at Advanced level. At Advanced level, teachers usually do not use any teaching and learning aids in their teaching of mathematics. Even at 'A' level learners can understand the concepts of permutations and combinations if they are taught from what they have already experienced. It may not be necessarily the game of pada but any other activity which is familiar to them.

Children must learn school mathematics in a way that will make them want to think mathematically rather than in a way that will make them want to avoid mathematics at all costs. Thus the use of games such as pada in the teaching and learning of school mathematics is one way of motivating the learners. These ideas from the game of Pada can be used in introducing the concepts so that learners can understand them better before moving to abstract problems. Games can also be used to reinforce ideas. Mathematics is not a solitary activity. It should be done and learned with others. Games and other activities provide an opportunity for learners to work together. From the study the children learned how to play the game of pada from their peers, so teachers can also make use of the gifted learners to help those who are less gifted in mathematics. Mathematics lessons can be more successful if they are organized so that students play a more active role and the mathematics studied is more clearly connected to a sensible context. If the students are to develop the power to use mathematics productively once they leave school, they need opportunities to use it productively while they are still at school. The use of games is one way of providing a context that can help students enjoy and understand mathematics and be able to apply it in their everyday lives though it is not a guarantee for success since there are children who do not like playing. However the success of games in teaching depends on the teacher's talent in asking probing questions and also in choosing the appropriate game for the set objectives. A lot of researches into the mathematical ideas embedded in games have been carried out around the world, for example the mathematics in the games of nhodo and tsoro by Masiiwa (2001), Cowry games in Cote d'Ivore by Doumbia (1989), a variety of games examined by Knight (2003) in Jamaica and Kenya and the game of mu torere explored by Ascher (1990) in New Zealand. These studies uncovered the mathematical ideas that are hidden in the games but most of the teachers of mathematics in schools are not aware of these findings. Thus there is need for mathematics teachers and researchers to work together.

CONCLUSION

The study explored the mathematical ideas that are found in the indigenous game of pada. It was revealed that a lot of mathematical ideas are found in the game of pada and these include permutations, probability, counting, geometrical construction, inverse variation, projectiles and many others. This game also teaches children some behavoural aspects of concentration, following instruction and endurance among others. The study demonstrated that indigenous games can be utilized by both teachers and children to develop a liking for Mathematics by using what the children already know.

RECOMMENDATIONS

There is need for mathematics teachers to be informed about the research results, which show the existence of mathematical ideas in different cultures. Mathematics journals can be sent to schools so that the teachers become aware of the researches that have been done in their field. However, in Zimbabwe it may be difficult to do so due to economic hardships. Workshops can also be made use of to disseminate the research results. There is also need to prepare mathematics teachers who will be able to investigate mathematical ideas and practices of their own cultural ethnic and linguistic communities and who will look for ways to incorporate their findings into their own teaching. In other words teachers should be trained to make use of mathematical ideas from the students' cultures. There is need for teachers to make mathematics more relevant by linking it with activities familiar to the students so that they become motivated to do the subject. Teachers need to move away from the chalk and talk way of teaching mathematics and try to involve the learners as much as possible.

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