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Hunter-gatherer Approach to Math Education - Everyday Mathematics in a San Community and Implications on Technology Design

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Abstract. K-12 math education is struggling as despite obvious job market benefits, several students choose to discontinue math education when given the possibility. At the same time, advances in learning technologies now enable modes of learning that were impossible up until ten years ago. In this study we analyse math education from scratch by returning to the hunter-gatherer time period and empirically observing how mathematics is present the lives of a San tribe in Southern Namibia with ethnographic analysis. With this work, we propose two high level design considerations for integrating math learning technologies with the hunter-gatherer way of living: (1) integration of learning technologies and real world objects; and (2) the introduction of physical activity and social communication to math education. We discuss how these two design considerations could boost students' motivation to continue learning math also beyond the formal school environment.

Keywords: Mathematics · Education · Hunter-gatherer · Evolutionary psychology · San people

1 Introduction

Mathematics has been identified as one of the most important if not the most important school subject at primary and secondary schools in terms of students' future prospects in the labour market [1, 2]. It is the core subject in the STEM fields which governments have acknowledged creates jobs and which citizens need in their daily lives in industrialized societies [3]. At the same time, mathematics is perceived as boring or mundane by a significant proportion of students, and when given the choice, many decide to discontinue studying it despite obvious benefits [4, 2].

As mathematics is a subject that heavily builds on top of prior knowledge, perceived difficulty and lack of confidence in abilities have been shown to be the main reasons for students to discontinue their learning [5]. To counter this, educators could invoke strategies such as teaching learning to learn [6], which in the case of math can mean tolerating challenge and not being discouraged when facing difficult problems [5]. Formal mathematics education historically advances at a certain rate and students who fall behind have trouble catching up. Educational math games and technologies have been proposed as solutions to these problems. Here the pedagogical quality [7] and technical quality [8] are important, but more holistic design and ideas are needed to create effective learning solutions [9].

In this study, we take the evolutionary psychology approach to educational math technology design in that we focus on the hunter-gatherer way of living which the homo sapiens and our primate ancestors lived off for up to several millions years before the agricultural revolution some 10k years ago [10]. We gather empirical evidence from one of the last cultures on earth which followed the hunter-gatherer lifestyle: the San people in Northern Namibia. For this analysis, we formulate the following two research questions that guide our work:

RQ1: What mathematics can we observe in the daily lives of the hunter gatherers?

RQ2: What design considerations can we draw from the hunter gatherers for mathematics learning technologies?

2 Theoretical background

2.1 Educational math technologies

The types of educational math technologies are numerous. There exists games, learning assistant tools, study diaries, technologies with visual, audio and force feedback, technologies with various sorts of input and so on. A single category of educational math games contains thousands or even tens of thousands of apps on popular market places [7]. Recent work has emphasized that it is important for math learning technologies to support students' deliberate practise [7, 11] i.e. instead of routine drill-and-practise tasks, students should be pushed to deliberately improve their skills with tasks that require problem-solving, conceptualization, reflection and deliberate pushing for further development of skill [11].

As primary and secondary level math teachers must adapt their teaching to match the slowest learners, this inhibits the most talented students from advancing their mathematical skills as fast as otherwise possible. Educational technologies can assist in this situation by introducing personalized learning, allowing students to proceed each at their own pace. Another advantage of educational technology is that it can make learning fun and motivating [8]. Math learning technology can also provide modes of learning that were previously not possible.

2.2 Evolutionary psychology and the hunter-gatherers

Evolutionary psychology has been suggested as a meta-theory for answering questions such as why humans play [12] and what kinds of activities appeal to humans [13]. For example, scholars have discussed how dormant territorial control instincts may be invoked by games [14, 15] and why children universally like to practise fighting, climbing trees and taking care of babies through playing [13]. This way, evolutionary psychology can act as a theory that guides the design of educational math games.

One of the pioneers of observing the mathematics of hunter-gatherers is Peter Denny [16, 17], who conducted research in particular among the Inuit, Cree and Ojibway hunters. Denny argues that mathematics has little use in hunter/gatherer societies [17]. The reasoning is that hunters adapt to the surrounding environment as they are dependent on wildlife for food. While agricultural and industrial societies depend on making changes to their environment to live, hunter-gatherers need specific knowledge about their environment but have no need or desire to change it. They know that any action that throws their environment off balance can lead to the loss of food. Basic mathematics such as counting can become useless in a way of living where every place and item is known by their name and characteristics [17]. It follows from here, that math is not an inherent skill in the same way as pattern recognition is, and instead, it needs to be learned [11]. To do this, education is needed, and here we need to investigate how educational technologies could serve the hunter-gathering mind of humans to make mathematics engaging, natural and fun. Previous work has investigated integrating math with almost all school subjects such as music [18] and computation [19], and findings from these studies invite research into looking at what new areas of life mathematical thinking and learning could potentially be combined with.

3 Empirical Study

3.1 Study process and participants

In this study as a primary method for uncovering the mathematics and opportunities for learning mathematics in the selected San community was ethnographic analysis [20]. We harnessed the knowledge of two informants who had lived in a San community in northern Namibia their entire childhood, as well as conducted specific on-sight observations in autumn 2018. We received permission from the locals to participate in the research and to publish photographs where they, or items they created appear. Interviews about the items and daily lives were conducted in Oshiwambo, the participants' native language. In our reporting we refer to the locals with pseudonyms.

Three San individuals who work as art producers were interviewed: designers Tom and Mika, and a musician Olavi. All three were male aged between 40 and 70. Their education levels were as follows. Tom finished only Grade 1; he cannot read nor write. By contrast, Mika and Olavi can read and write. We interviewed the three of them about mathematics. None of the three perform any mathematical measurements when producing their artwork and do not see any need for it. Tom did not have knowledge about geometric shapes, while Mika was able to identify some letters and triangles on his artwork. They only make different shapes and designs for their products to make them look good and beautiful. Their artwork is a way for them to generate income to support their families. They sell products, such as knives, omaholo (cups), bowls, arrows, and spears, to local people at different prices depending on the size. Olavi only participates in music and dancing, and he sees and opportunity to make an income out of it for him in the future.

Fig. 1. Omaholo traditional cups (left) and an air blowing fire chamber (right)

3.2 What mathematics we observe in the daily lives of the San people

Figure 1 (left) depicts Omaholo traditional cups that are made from the Omupopo or Omupalala trees on the left. These omaholo are used for drinking Oshiwambo alcoholic beverage (e.g. omalunga, omagongo, ombike). We notice that the cup design features various geometric shapes. The omaholo themselves can be used for mathematical measurements. With regards to the inner part, it can be used to measure the volume of a liquid once we know the diameter and height of the cup. With regards to the outer part, the artistic decor enables the learning of geometric shapes and related mathematics. Despite this potential for learning mathematics, Tom did not identify any geometric shapes nor saw need for it. Mika could identify triangles, but did not develop this understanding further.

On the right side of Fig 1 we see an air blowing chamber that the San people in the observed village use to light a fire. In the past, people used Oryx horns instead of tubes (i.e. metal iron). At present, people use metal tubes, especially bicycle parts, because Oryx is now highly protected by the government. The chambers are made from the local tree Omukanga. Here, we can deduce mathematical shapes from the design, such as cubes and cylinders. Subsequently, we can find and calculate the volume and the length of the blowing tubes and the channels. In addition to mathematics, this fire creation chamber in particular serves as a construal [21] to teach physics. For example, the following can be observed: (1) The bigger the tubes, the higher the resulting air pressure will be; (2) If the tubes (metal iron) are long, the pressure will be low; (3) The handle stickers, which are circular in shape, are used for air volume control. The more accelerated the pumping or blowing of air, the more charcoal oxidizes in the iron casting; and (4) The length of the tubes mostly depends on the size of the blower's chamber.

Music instruments of the San people are displayed in Fig 2. The longest instrument here is the bass and the shorter ones produce higher notes. Here we identify several types of mathematics as well. Again, we can observe cylinders and ovals, find out the volume of the musical instruments, observe that the diameter and length of the instruments determine the tones and sound that is produced ans so on. In addition, the music that is produced with the instruments can be used to teach mathematics [1, 18]. For example, rhythm can be written down with decimal or fractional numbers, and several numerical representations also exist for pitch.

Fig. 2. These instruments are used to produce musical sound through a blowing technique. They are made from the roots of Ontyu, a local shrub. Roots are dinged from the soil, and this process usually takes about three hours.

3.3 What mathematics we observe in the hunting and gathering traditions of the San people

Knives play an important part in the culture of the San people. Knives are made by the people themselves, and are always in the shape of a leaf, as shown in Figure 3. This shape makes it easy to cut and penetrate into something. To ensure safety, the knife must be in its full compartment and always kept with the head up. The wooden part is made from local trees Omupopo or Omupalala, while the metal part is made from either an old panga knife or a knife razor, regarded as the best and strongest material. With regards to mathematics, the knife's body has an oval form. It has a 3-dimensional figure, with a head and a tail. The tail is almost diagonal in shape, while the head is circular. Here we observe that there are diagonals and other geometric shapes (e.g. triangles) in the way the knives are decorated.

Fig. 3. Traditional knives made by the San.

As the San people are among the final hunting-gathering cultures left on earth, we wanted to specifically focus on this aspect of their lives. Unfortunately, they have been forced to stop living this way due to restrictions on movement, laws forbidding hunting and territory claimed by landlords. Because of this, we had to interview the village elders specifically to uncover this lost knowledge. In Fig 4 we see a hunting pouch and arrows that up until 1990's were used by the San to hunt wildlife. Today, only a single such pouch remains in the village. On the right of Fig 4 we see a 3-level basket that was used to store gathered fruit and other goods and carried on the back. Today, these types of baskets are mostly used as decorations or sold to tourists.

Exemplar mathematics embedded into the baskets in Fig 4 are as follows. Knowing the amount of raw material used for one of the baskets, we can estimate how much dry palm leaves was needed to make the other two baskets (assuming that the thickness of the different baskets is the same). This estimate is based on the fact that the area depends quadratically on the size: the area of a shape x times larger is x^2 times greater. This also holds for areas in three dimensions, namely the area of a spherical segment (the shape of our baskets) is proportional to the square of its diameter. Knowing the storage capacity of one of the basket we can estimate the capacity of the other two baskets. This estimate is based on

Fig. 4. A hunting pouch and arrows (left) and a traditional 3-level basket used for gathering (right)

that spatial volume depends cubically on the size: the volume of a shape x times larger is x^3 times greater. That is, in our case, the volume of a spherical segment is proportional to the cube of its diameter. After the calculations, we check our estimate experimentally: we measure the weight and the storage capacity of each basket.

An essential element of the traditional hunting strategy of the San people is the observation of animal tracks. Tracking is a complex and challenging task and it is not limited to following an animal from footprint to footprint, but its goal is to understand the movement and behavior of the animals by interpreting their tracks. As pointed out by Liebenberg [22], tracking was the earliest manifestation of scientific thinking in human history. The tracks can be considered as symbols that contain implicit information about animals. Reading and understanding these symbols, as practiced by hunters of the San communities, is indeed a science that requires the similar intellectual abilities as modern mathematics. It is therefore reasonable to link the learning of mathematics with tracking experiences. Understanding the similarity between reading the tracks in the sand and reading the symbolic language of mathematics can help students develop a positive attitude towards mathematics.

4 Discussion

4.1 Design consideration for math technologies

Based on our observations as well as previous work [17], mathematics is not something that hunters-gatherer societies naturally develop. The question arises that as all mathematics beyond simple counting is learned, how can we motivate students to learn mathematics and think about the world in a more mathematical way. Via embedding mathematics into the everyday lives, it can become a natural part of thinking that enables further development of mathematical skills [23].

However, it is arguably not only the hunter-gatherers that benefit from embedding math into their daily lives. As hunter-gatherer societies manifest many of the natural tendencies that make humans happy [10], these societies can be seen as inspiration for the development of educational math technologies. Here we specify two fruitful design considerations that arise from our observations.

Use of everyday items as construals for learning mathematics We observed that several opportunities exist within the everyday lives of the San people for teaching and learning mathematics, both through everyday items but also through culture. Yet, this learning process is not automatic, and teaching is required to draw out the mathematics that is associated with the many observed items and habits. For technology designers this is a major challenge. Designers need to break free from the constraints of creating software and applications and move to create construals, tools to learn mathematics with.

Include more exertion and social communication into the learning of math Exertion and social communication are central to human behavior and something that modern societies lack. While doing mathematics is mostly working with pen and paper, there is no reason why mathematical thinking would not be introduced to exercise and social situations. In fact, dancing is a good example of a social and physical activity that also includes mathematics in the form of counting steps and keeping up with the rhythm. In our empirical work we showed that the musical instruments have a lot of music embedded into them, not to mention the music itself that is played [1]. Other technologies such as location-based apps [15] could also be utilized to combine exercise, social interaction and mathematics.

4.2 Design considerations for the Namibian school system

The findings suggest possibilities of promoting the use of mathematical knowledge of hunter-gatherers in the Namibian school curriculum, especially for cultural confidence [24], and contributes to the understanding of African culture in math learning technologies. The integration of local artwork in school subjects may create confidence, and meaningful learning of mathematics among students, especially those who perceive mathematics as a difficult subject. Furthermore, integration of an important school subject, mathematics, to the local culture also serves to preserve the culture, as it gains more value through its association to mathematics.

4.3 Limitations and Future Work

Due to the large scope of our approach and the study topic, the resulting design considerations remain at a general level. Our findings show promising research directions which future work could explore further. Especially embedded math learning technologies and technologies supporting everyday mathematical thinking are worth investigating further. Furthermore, this work opens the research avenue on how the hunter-gatherer tendencies of humans could be utilized to boost the learning of math and learning in general. One of the criticisms towards our approach is that it might not be as cost or time-efficient as currently favored modes of teaching. Also while mathematical thinking outside the classroom setting is important, it remains unclear what is the best way to achieve this goal.

5 Conclusions

In this work we showed that geometry, symmetry, combinatorics and other kinds of mathematics are present ubiquitously in the San community and other human societies, but without additional teaching and support, humans do not learn to think about their everyday objects and activities in mathematical terms. Here we proposed two ways in which we can re-imagine mathematics education from the perspective of observations in the hunter-gatherer society: (1) the use of props and real world objects as contruals through which math can be learned; and (2) introducing physical activity and social communication more prominently into math education. The main benefit of this kind of an approach is that mathematics will be integrated into the daily lives more holistically. While pen and paper are still useful tools for learning and doing mathematics, seeing mathematics in the everyday world can guide thinking and lead to further development of mathematical knowledge.

References

1. S. Laato, R. Shivoro, N. Pope, F. Gideon, and E. Sutinen. Identifying factors for integrating math and music education at primary schools in namibia. In *2019 IEEE International Conference on Engineering, Technology and Education (TALE)*, pages 1–8. IEEE, 2019.
2. Jouni Pursiainen, Jarmo Rusanen, and Sauli Partanen. Lukion tärkein ainevalinta. *Dimensio*, 4(2016):21–24, 2016.
3. Valerie F Reyna and Charles J Brainerd. The importance of mathematics in health and human judgment: Numeracy, risk communication, and medical decision making. *Learning and Individual Differences*, 17(2):147–159, 2007.
4. Kirsti Kislenko, Barbro Grevholm, and Madis Lepik. Mathematics is important but boring: Students' beliefs and attitudes towards mathematics. In *Nordic Conference on Mathematics Education: 02/09/2005-06/09/2005*, pages 349–360. Tapir Academic Press, 2007.
5. Margaret Brown, Peter Brown, and Tamara Bibby. "i would rather die": reasons given by 16-year-olds for not continuing their study of mathematics. *Research in Mathematics Education*, 10(1):3–18, 2008.
6. Elena Novak and Janet Tassell. Video games that improve 'learning to learn': Focus on action video game play elements. In *2017 IEEE 17th International Conference on Advanced Learning Technologies (ICALT)*, pages 142–144. IEEE, 2017.

7. S. Laato, R. Lindberg, T.H. Laine, P. Bui, B. Brezovszky, L. Koivunen, O. De Troyer, and E. Lehtinen. Evaluation of the pedagogical quality of mobile math games in app marketplaces. In *2020 IEEE International Conference on Engineering, Technology and Innovation (ICE/ITMC)*, pages 1–8. IEEE, 2020.
8. P. Bui, G. Rodríguez-Aflecht, B. Brezovszky, M.M Hannula-Sormunen, S. Laato, and E. Lehtinen. Understanding students' game experiences throughout the developmental process of the number navigation game. *Educational Technology Research and Development*, pages 1–27, 2020.
9. Kristian Kiili. Digital game-based learning: Towards an experiential gaming model. *The Internet and higher education*, 8(1):13–24, 2005.
10. Yuval Noah Harari. *Sapiens: A brief history of humankind*. Random House, 2014.
11. Erno Lehtinen, Minna Hannula-Sormunen, Jake McMullen, and Hans Gruber. Cultivating mathematical skills: From drill-and-practice to deliberate practice. *ZDM*, 49(4):625–636, 2017.
12. Zack Mendenhall, Gad Saad, and Marcelo Vinhal Nepomuceno. Homo virtualensis: Evolutionary psychology as a tool for studying video games. In *Evolutionary Psychology and Information Systems Research*, pages 305–328. Springer, 2010.
13. Anthony D Pellegrini and Peter K Smith. *The nature of play: Great apes and humans*. Guilford Press, 2005.
14. Samuli Laato, Bastian Kordyaka, AKM Najmul Islam, and Konstantinos Papangelis. Landlords of the digital world: How territoriality and social identity predict playing intensity in location-based games. In *Proceedings of the 54th Hawaii International Conference on System Sciences*, page 744, 2021.
15. Konstantinos Papangelis, Alan Chamberlain, Ioanna Lykourentzou, Vassilis-Javed Khan, Michael Saker, Hai-Ning Liang, Irwyn Sadien, and Ting Cao. Performing the digital self: Understanding location-based social networking, territory, space, and identity in the city. *ACM Transactions on Computer-Human Interaction (TOCHI)*, 27(1):1–26, 2020.
16. J Peter Denny. Context in the assessment of mathematical concepts from hunting societies. In *Human assessment and cultural factors*, pages 155–161. Springer, 1983.
17. J Peter Denny. Cultural ecology of mathematics: Ojibway and inuit hunters. *Native American mathematics*, pages 129–180, 1986.
18. Samuli Laato, Teemu Laine, and Erkki Sutinen. Affordances of music composing software for learning mathematics at primary schools. *Research in Learning Technology*, 27, 2019.
19. Samuli Laato, Sampsa Rauti, and Erkki Sutinen. The role of music in 21st century education-comparing programming and music composing. In *2020 IEEE 20th International Conference on Advanced Learning Technologies (ICALT)*, pages 269–273. IEEE, 2020.
20. Martyn Hammersley. Ethnography. *The Blackwell encyclopedia of sociology*, 2007.
21. Antony Harfield, Rene Alimisi, Peter Tomcsányi, Nick Pope, and Meurig Beynon. Constructionism as making construals: first steps with js-eden in the classroom. *Proceedings of Constructionism 2016*, pages 42–52, 2016.
22. Louis Liebenberg. *A field guide to the animal tracks of southern Africa*. New Africa Books, 1990.
23. Ubiratan D'ambrosio. Multiculturalism and mathematics education. *International Journal of Mathematical Education in Science and Technology*, 26(3):337–346, 1995.
24. Paulus Gerdes. On mathematics in the history of sub-saharan africa. *Historia mathematica*, 21(3):345–376, 1994.