THE INCORPORATION OF THE GEOMETRY INVOLVED IN THE TRADITIONAL HOUSE BUILDING IN MATHEMATICS EDUCATION IN MOZAMBIQUE:

The cases of Zambezia and Sofala Provinces

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A thesis to be submitted in the Faculty of Education, University of the Western Cape, in fulfillment of the requirements for the degree of Doctor of Philosophy (PhD)

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October 2009

"Generally, we consider culture to be:

one -- the way, without any mental labour effort, people think, feel and behave;

two -- the way people see and interpret the nature and the society they live in;

three -- the way they conceive the role of the man before that nature and that society;

four -- the way they act or tend to act in order to realize themselves as men and as people;

Synthesizing:

We consider culture of a people the conception that they have of the world and life as well as of their role in the unity of that world and that life. That conception is conditioned by various factors within them the way and degree of the production development which by its turn determines the social organization and the corresponding relationships between different social stratums, the nature of the ruling class, the degree of the development of the scientific and technical knowledge and up to the geographical and climatic context."

Samora Machel

In INDE (Editor), 1989, p.188, (from *Tempo* magazine, Maputo, 02-01-1979)

Traditional house builder's Status

In spite of the fact that this work is more related to mathematics and mathematics education I feel the obligation to speak a little bit about the traditional house builder's status then, speaking about his status among the Mozambican society, specially from the Provinces of Zambezia and Sofala agreed I'm trying to present my humble gratitude to all house builders, who accepted to be interviewed and/or to be observed while working, so that the study could be possible.

Some of the house builders are at the same time carpenters. Therefore, when they have no house to build, they produce doors, windows, chairs, tables, etc., whereas the others are only house builders. These latter ones, when they don't have houses to build become common citizens and go working in their own fields or take a seasonal job. However, the respect for the two house builder's categories is the same, depending essentially on the *beauty* (perfection) and the durability of the houses built by them associated with the relatively low prices that they ask for the job.

In order to give a small idea of the traditional house builder's importance among the rural Mozambican society, I can indicate that 85,8% of the dwellings in Mozambique (93,9% in the rural areas) are traditionally built and 81,8% of the dwellings are thatched with grass or straw. (INE, 2001)

DECLARATION

I declare that The incorporation of the geometry involved in the traditional house building in mathematics education in Mozambique: the cases of Zambézia and Sofala Provinces is my own unaided work, that it is being submitted for the Degree of Doctor of Philosophy in the University of the Western Cape, Bellville, that it has not been submitted before for any degree of examination in any other University and that all the sources I have used or quoted have been indicated and acknowledged by complete references.

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(Daniel Bernardo Soares)

Bellville, October, _____, 2009

DEDICATION

To late Stieg Mellin-Olsen, the father of the GRASSMATE-Program.

To my late mother Madalena (Dona Mãezinha),

who even widowed invested in my intellectual education.

To my wife Fernanda (Nanda)

and (to) my daughters Danna, Eufrásia (Nhanhy) and Natacha,

for their love and understanding.

Abstract

The incorporation of the geometry involved in the traditional house building in Mathematics Education in Mozambique
The cases of Zambézia and Sofala Provinces
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Moved for (i) curiosity and interest for architecture, (ii) necessity of cultural preservation of traditional house building techniques and (iii) will for identifying the mathematics, especially the geometry, involved in the traditional house building, in order to suggest it's incorporation in Mathematics Education, I decided to do this research as theme of Ethnomathematics, then Ethnomathematics can be seen as the study of the relationship between Culture, Mathematics and Mathematics Education.

I made my research guided through two main questions:

(1) *What mathematics is involved in the traditional house building?*

(2) *How can this knowledge be incorporated in Mathematics Education?*

In this study I consider traditional house in Mozambique a house with (i) walls made with reed, sticks, wood or bamboo strips, covered with mud, with grass or straw, and (ii) roofs thatched with grass, reeds or straw.

For the data collection I (1) made interviews and observations in southern Zambézia (by Echuwabu speaking house builders) and in central and northern Sofala (by the Cisena speaking house builders), (2) studied some works on African house building, (3) read some inquiries from the years 1980s about house types, kindly lended by Sofala's Cultural Heritage Archive, and read some works that relate socio-cultural activities and mathematics education.

Among others I came across eight methods for the rectangle construction, two methods for placing posts vertically, two methods for placing beams horizontally and the translation of 27 (from 28) basic terms for Elementary Geometry into Echuwabu and into Cisena. All these methods are geometrically analyzed and some tasks for the school mathematics suggested.

Some of the conclusions of the study were that *traditional house building* is only learnt by observation and active participation, that the mathematics involved in it can be incorporated in the category of *folk mathematics*, given that it develops in a working activity, and that the incorporation of the mathematics related to traditional house building in mathematics education has the advantage that house building in rural Zambézia and Sofala is *gender free (both male and female people participate in traditional house building)*, and that teachers and future teachers recognize that the origin of the geometry is the practice -- and that can facilitate the incorporation of mathematics related to traditional house building in Mathematics (and teacher) Education in Mozambique.

One of the suggestions of the thesis is that more cultural aspects and production techniques related not only to mathematics, but also to other sciences (and technology?) must be investigated and then used, so that, at least in the first school grades, the pupils can work with concrete examples of their daily lives and culture, and not only with examples from the "standard" text books.

The pages in the thesis are indicated through numbers "1, 2, 3 …" and with de indication of the chapter, in the footer. Before chapter 1, Introduction, the

pages will be indicated with "**i, ii, iii, …** ". In the Appendix the pages are indicated with "**A**.1, A.2, A.3, …".

All page numerations lie below, at the right-hand side of the page.

October 2009

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Abbreviations

ARPAC	Cultural Heritage Archive
Ed. or ed.	Editor
Fig.	Figure
INDE	National Institute for the Development of Education
INE	National Institute of Statistics
ISP	Instituto Superior Pedagógico (Higher Pedagogical Institute)
NELE	Núcleo Editorial do Livro Escolar
Pl.	Plural
Sing.	Singular

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Acknowledgments

Thanks go first to Professor Paulus Gerdes, who showed me, first as my lecturer and later as colleague the first steps in the fascinating field of Ethnomathematics, the theory that I used for this study.

I am grateful for the very useful suggestions, teachings, advices, patience and fondness of my supervisors: Prof. Jan Persens, Prof. Ole-Einar Torkildsen and Prof. Trygve Breiteig.

I am also grateful to my former head of the Mathematics Department of the Universidade Pedagógica (Beira Campus), Jan Draisma, for having chosen me for the GRASSMATE-Project.

Thanks go also to Fátima Batalhão, Angela Koch and Carlos Baptista Victorino for the translation from Portuguese into English of my first Thesis Proposal, the *cradle* of the study.

Research materials from the ARPAC-Sofala (Cultural Heritage Archive) were useful and were added to my data. Therefore, my thanks go to José Chuva Cafuquiza, the Director of the ARPAC-Sofala.

I am also grateful to all my colleagues of the Mathematics Departments at the Universidade Pedagógica (Maputo and Beira), especially Dr. Adriaan Lucas Rijkeboer, Dr.Marcos Cherinda and Dr. Abdulcarimo Ismael, to my former students, especially Evaristo Murimo, Alberto Línder (late), Fonseca A. Fonseca, Elias Alberto, Lucas Tomás Mango, Álvaro Zacarias, Júlio Waéte Chicote, Eugénio Fernandes and Mariano Jaime for the collected data, to all interviewed house builders, especially Sualé Isaac Sualé and to my late mother, Madalena, for having accompanied me to the first interviewed house builders in Zambezia Province.

My special thanks to the Norwegian universities' funding agency (NUFU) and to the supervisors team: Professors Øyvind Mikalsen, Cyril Julie, David Muthetwa (the Chief), Jan Persens, Ole-Einar Torkildsen, Trygve Breiteig, Lorna, Svein etc., for everything.

My special thanks go also to my colleagues in the Graduate Studies in Science, Mathematics and Technology Education (GRASSMATE) Abílio Mapapá, Sarifa Fagilde, Monde Mbekwa, Eddie Smith, Cribert Munetse, Mogege David Mosimege, Larry Kannemayer (late), Godwin Hungwe, Vincent Lebeta (late), Kalvin, Eunice, Hileni, Victoria, Chipo, Charles Opolote, Maroni, Bernhard, Mark, etc. for the friendship and the unforgettable seminars.

Finally, my special thanks go to Mr. Carlos Machili, at the time the Rector of the Universidade Pedagógica, Mozambique, for having given me some months free in order to finish my Data Collection, Reading for and Writing of the first complete draft of the thesis.

General Index

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1 Introduction and Statement of the Problem

1.1 General remarks

Mozambican Children, both urban and rural, grow up being exposed to mathematical concepts particularly in the field of geometry. Indeed, they are surrounded by geometrical shapes even though they may not be consciously aware of it. For example, they would handle glasses of cylindrical shape or in the form of a truncated cone, plates and pots are most often of circular shape, and balls are spherical. Outside the home environment children observe window panes, burglar bars, drain covers and buildings of different and interesting geometrical shapes. In some rural areas children live in houses (or traditional homes) with a base of a rectangle (including square) or a circle and roofs in the shape of a pyramid or a cone.

There are also mathematical elements in nature as well. If one takes a closer look at a sunflower head and if one is sufficiently prepared ,a spiral shape would be identified a right away. The way in which the branches of a pine tree are formed (reminds one of)/brings to mind the vertical translation of the graph of an absolute value function.

The researcher always had the scant idea that it is not at school that one would have a first encounter with mathematical ideas. Therefore, he (the researcher) became enthusiastic about the extent of mathematical thought and behavior in out-of-school activities of both children and adults. Having grown up in Mozambique and being aware of the extent to which traditional houses are still used in this country, the researcher has decided to do a study on the mathematics involved, in particularly the geometry, which house builders in Mozambique know and which but is hidden in their work.

In addition, he/the researcher decided to investigate how the knowledge one may gain from the geometry of traditional house building, and the geometrical thinking associated with it, can be used in the teacher education. As Shirley (2001, p. 86) writes, “teachers must learn special instructional skills to accommodate different backgrounds and different learning strategies”. An important objective of this investigation was to determine how the mathematics in the classroom can be related, as close as possible, to the mathematics that children bring with them from outside the school in order to minimize the so-called *psychological blockage*. The researcher intends to attain this objective through teacher education. Obviously the study of the Mathematics related to traditional house building will constitute a large measure of contribution for this big and important objective. Then, as Shirley further writes

> it has now been recognized that culture can determine the student’s feeling toward participation in class discussion, initiating questions, acceptance of authority, memorization of facts, seeking innovative ways of understanding, and many other aspects of classroom education (Shirley, 2001, p. 86).

Or, as Martin writes,

> The belief that mathematics is a body of truth independent of society is deeply embedded in education and research. This situation, by hiding the social role of mathematics behind a screen of objectivity, serves those groups which preferentially benefit from the present social system of mathematics (Martin, 1997, p. 168).

Further, commenting on the document of the National Council of Teachers of Mathematics (2000), Shirley writes that “instructional programs should enable students to ‘communicate their mathematical thinking coherently and clearly to peers, teachers, and others’”, and that “the teacher must encourage the participation of all and emphasize the value of everyone's contribution to the learning process" (Shirley, 2001, p. 86).

It is expected that the Mathematics hidden in traditional house building would not be only related to geometry, but the researcher has the conviction that the geometrical component in this activity seems to be quite evident. By recognizing the value that people shared in several ways, in this case by building houses, the researcher decided to do the study on this topic as a theme of Ethnomathematics. In this context Ethnomathematics can be seen as the study of the relation among culture, mathematics and mathematics education Gerdes (1996, p. 909) writes, Ethnomathematics is a relatively new field of interest which may be defined as "the cultural anthropology of mathematics and mathematical education", i.e., one field of interest "that lies at the confluence of mathematics and cultural anthropology".

Struik agrees also with the importance of ethnomathematical study for education and comments:

> If pupils from the villages (and ghettos) come to school and enter modern classrooms, will not the indigenous mathematics in their upbringing facilitate their acquisition of the modern mathematics of the classroom? This use of the 'intuitive' native mathematics may well be of help in easing the mathematical angst we hear so much about (Struik, 2003 [1998], p. xi).

1.2 Traditional house and research questions

Now the researcher will try to explain what he considers to be a traditional house. He will not define a *traditional house*, but he considers a traditional house, in Mozambique, particularly in the provinces of Sofala and Zambézia, a house with the following characteristics:

(1) walls made with reed, sticks, wood or bamboo strips, covered with mud or covered with grass or straw, and

(2) roofs thatched with grass, reeds or straw.

However, agreeing partly with Larson and Larson (1984, p. 42) when they write that "... we regard purchased elements such as factory-made doors, panes of glass, ..., as improvements of a traditional dwelling".

In Mozambique one can find traditional houses built with raw bricks, but this is not the case in Sofala or southern Zambézia.

The main questions that the researcher will try to answer in the thesis are:

1. *What mathematics is involved in the traditional house building?*
2. *How can this knowledge be incorporated in Mathematics Education?*

Both the first and the second questions seem to be very wide. But, after some fieldwork the researcher came to the conclusion that one could continue with these two research questions.

About the first question one can say that, on one hand, there are not the children who build the houses, but in rural Sofala and Zambézia both boys and girls aged about 5-years-old, (the schooling age in Mozambique is after 6-years and above) are involved in house building as helpers of house builders, building very small houses . The boys, even if they do not want to become house builders, they begin to build their own houses or simply sleeping annexes at a very early age (13 to 15-year). On the other hand, Gerdes writes that "teachers should learn to recognize and incorporate all sorts of 'informal' or 'hidden' mathematics 'known' by the *pupils* and *their parents*" (Gerdes, 1986, p. 24, *italic by the researcher*), and the researcher agrees with him. To that, one can add that "Ethnomathematics in the elementary classroom is where the teacher and students value cultures, and where cultures are linked to curriculum." (Harding-DeKam, 2007, p. 1), or, as

Diez-Palomar, Simic & Valey (2007) write, "… it is important aspect of incorporating students' funds of knowledge into a culturally relevant mathematics curriculum for teachers to learn more about their students' lives and experiences." (Diez-Palomar, Simic & Valey, 2007, p. 30)

About the second question, one could formulate an alternative question like *how can this knowledge be incorporated in Mathematics Education in the Provinces of Sofala and Zambézia*, given that the study was done only in these two Mozambican provinces. But, given that in mathematics education the researcher emphasizes *teacher education*, and that the Mozambican reality in terms of teacher education -- the student teachers are coming from everywhere, and often their courses can work everywhere in the country -- forces one to think that, if this study is of value, their results, or at least the study findings and the recommendations thereof, will be used in Teacher Education in Mozambique, not only in Teacher Education Colleges of Sofala and Zambézia Provinces.

Besides, it is a goal of the researcher to do a similar study in other regions of the country, later on, so that comparisons can be made. The study done in parts of Sofala and Zambézia Provinces is simply a first step of a broader study of *what mathematics is involved in the traditional house building in Mozambique.*

One can also justify the second research question by quoting Gerdes and Bishop. Gerdes writes:

> At the same time, by using (in this sense) traditional production techniques from all over the country, knowledge is becoming less tribal, less regional: knowledge or culture is becoming national (important in a process of nationbuilding as the case of Mozambique) (Gerdes, 1986, p. 37).

And Bishop furthermore completes writing that "knowledge is open to all and is not a possession of certain members of the cultures" (Bishop, 1986, p. 62).

1.3 Thesis composition

This work is divided into ten Chapters, namely:

1 - Introduction and Statement of the Problem

2 - Rationale for Study

3 - Theoretical Framework

4 - Literature Review

5 - Research Methodology

6 - Data and data analysis on houses of rectangular/square base

7 - Data and data analysis on houses of circular base

8 - *What mathematics is involved in the traditional house building in Zambézia and Sofala Provinces?* (A general data analysis)

9 - *How can the mathematics involved in the traditional house building be incorporated in Mathematics Education?*

10 - Conclusions and Recommendations

In addition to these ten chapters, the thesis includes a general Index, a List of references, a List of figures, a List of tables and an Appendix.

In chapter 1, the researcher presents the main questions of the thesis and maps of the research area.

In chapter 2, the researcher justifies the study, i.e., he presents in this chapter the reasons which led him to the idea to do a research on traditional house building, and in chapter 3 the researcher presents the theory which was leading him in this research, viz., Ethnomathematics, justifies why Ethnomathematics and not another theory and explains his understanding of Ethnomathematics.

In chapter 4, the reader can find a summary of some relevant works from other authors about African Architecture, especially about traditional house building from Africa South of the Sahara Desert and some works on the use of cultural activities in mathematics classes and mathematics curriculum.

In chapter 5, the researcher presents the different methods and techniques used for the data collection, and explains how and for which kind of data each method or technique was used.

In chapter 6, the researcher presents the data on traditional house building of houses with rectangular base, where one can find different methods of rectangle construction, the description of wall and roof construction and the thatching, whereas in chapter 7, there is data on construction of houses with circular base.

In chapters 6 and 7 the researcher already presents some data analyses.

In chapter 8, the researcher presents a summary of different and, at the same time, relevant mathematical aspects found in (or related to) traditional house building.

In chapter 9, the researcher suggests some mathematical tasks for Mathematics Education, emphasizing where possible tasks for teacher education, using the traditional house building as starting point, as source, and in chapter 10 the researcher presents some conclusions of the research and some recommendations for different Mozambican Institutions and scholars.

1.4 The history of the thesis and fields of research

The idea of conducting this study started in 1991 in the researcher's Ethnomathematics lessons when the researcher's students gave an account of how traditional houses are build in their native regions followed by a scant comparative discussion. The field research was made from July-1997 until September-2002 in two Mozambican provinces, viz., Zambézia (1) and Sofala (2) (Fig. 1.1).

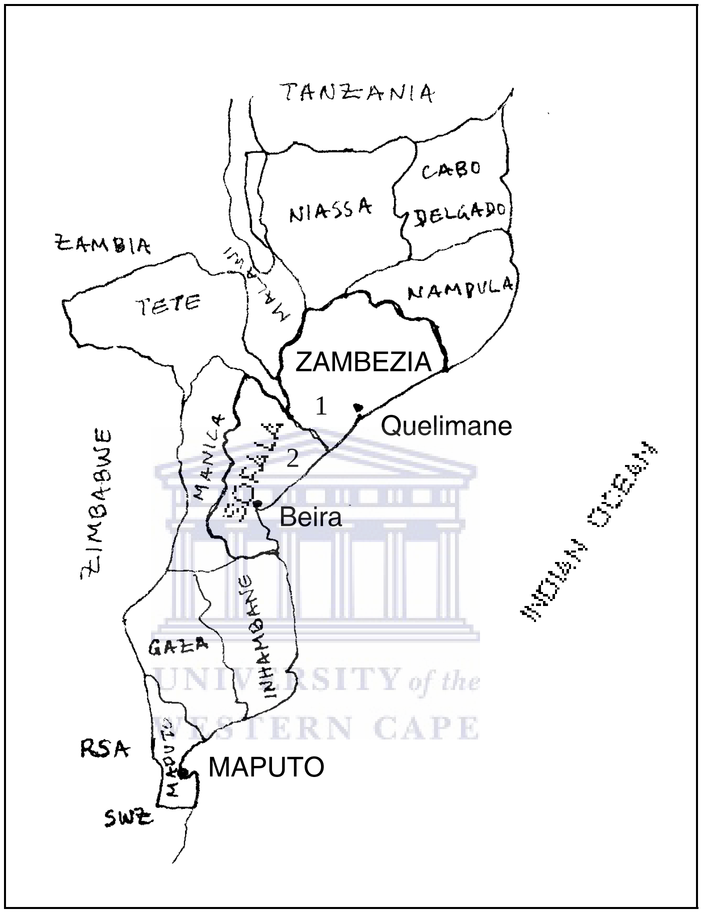


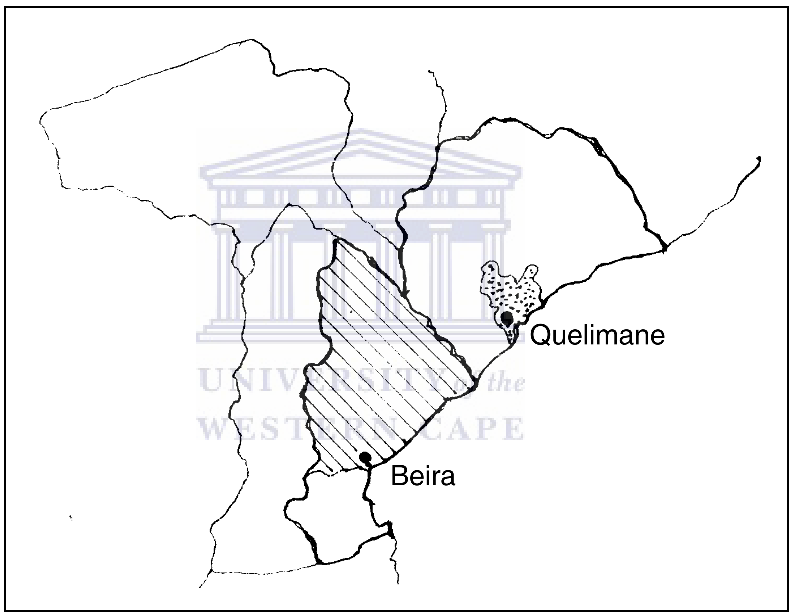
Fig. 1.1 Map of the Republic of Mozambique

In the Zambézia Province, *Echuwabu* speaking house builders (from the districts of Quelimane, Nicoadala and Namacurra) were interviewed and observed and in the Sofala Province, *Cisena* speaking house builders were interviewed and observed while working (See Fig. 1.2). In Sofala, house builders from the districts of Beira, Dondo, Nhamatanda, Gorongosa, Marínguè, Muanza, Cheringoma, Marromeu, Caia and Chemba were interviewed and/or observed.

Given the fact that the house builders didn't have all the same treatment --

some have been interviewed and observed while working, other house builders have been only interviewed or only observed or the researcher had with them only an unsystematic/unstructured conversation -- the researcher will not determine how many house builders were involved in this research. However, ten whole interview transcriptions are presented in the Appendix section.

The *Echuwabu* and the *Cisena* speaking people belong to the Bantu subgroups *Chuabo* or *Cuabo* and *Sena*, respectively.



Field of research in Zambézia Province

Field of research in Sofala Province

Fig. 1.2 Map of the field of the research

Altogether the field of the research occupies an area of 53437 km^2, being 5497 km^2 and 47940 km^2, in Zambézia and Sofala Provinces, respectively, -- area calculated according to Pililão (1989).

Sometimes, namely in chapters 6 and 7, the study seems to be a comparative study of traditional house building between Sofala/Zambézia and Botswana. But it is not the intention. This tendency to compare happened because (1) both Mozambique and Botswana are African tropical countries and (2) Larson and Larson (1984) did another thorough study on traditional housing in Botswana.

1.5 Limitations of this research

> The researcher agrees with Elleh (1997) when this author says that Architectural historians have shiedaway from writing a history of African architecture because the subject is vast, and no one knows exactly where to begin and where to end (Elleh, 1997, p. xiii).

The first desire of the researcher was to do a comparative study on traditional house building, that would cover all of the country of Mozambique. But, for time and cost reasons the researcher was obliged to limit his research to only a case study limited to parts of two of the ten Mozambican Provinces, viz., Zambézia and Sofala.

Due to time limitations, since the researcher was lecturing while he was doing data collection, it was not possible to physically follow carefully, , all steps of a process of house building, asking all the necessary questions. To correct this deficiency the researcher had the idea to video-tape vast parts of the building process in order to “see” the process several times at home and to make questions, but, once more, the lack of electricity in the rural areas did not allow him to use this method of data collection as was wished/planned.

Another limitation of the study was the language barrier. By presenting and analyzing the data, it was necessary, most of the time, to translate them from

Cisena or from *Echuwabu* into Portuguese and from this into English. The researcher spent a lot of time on the translations and as a result sometimes parts of the original meaning of some expressions could have been lost. For example, the researcher is not a *Cisena* speaker, even if he understands quite a lot of usual words, he needed help from (or cooperation of) some of his students, who served as interviewers and interpreters from Cisena into Portuguese, in Sofala Province.

Another limitation was the scarcity, in Mozambique, of literature on African, especially Mozambican, traditional house building with the desired detail.

The last limitation was the use of "independent" interviewers (researcher's students). Sometimes they didn't understand the "depth" or extent of some questions and were satisfied with superficial answers of the house builders, and most of the time it was not possible to revisit the interviewed house builders.

Next chapter, chapter 2, presents the reasons which led the researcher to the idea of doing a research on traditional house building.

2. Rationale for study

For this study the researcher found motivations in the daily life and in his experience as lecturer, in the objectives for school geometry and mathematics text books, in the literature on African traditional house building and in Ethnomathematics studies. He found also justification of the relevance, for Mozambique, of the research that he intended to do in recent doctoral theses of two Mozambican teacher educators.

2.1 Two general motivations for the study

Two main reasons led the researcher to choose this theme for his research: his interest in architecture and his involvement in Ethnomathematics.

Architecture, or simple construction work, was his dream when he was a child, but he turned out to be a lecturer and did not regret it, because he enjoys teaching and learning.

The researcher always, and sometimes strongly, admired the house builders because, in general, these people did not have access to formal education, i.e., did not attend school formally. On the other hand, to become, for example, an electrician, or a motor vehicle mechanic, one needs to attend school.

When he began lecturing History of Mathematics and Ethnomathematics, in 1991, as an assistant of Professor Paulus Gerdes at the ISP (Higher Pedagogical Institute) now known as the Pedagogical University, at Beira Campus, this admiration increased and was transformed into curiosity. The researcher did not mean curiosity in the sense of eagerness to know their architectural capacities, but he understood that they should have some knowledge of Mathematics, let alone Physics, especially mechanics. From that time on the researcher wanted to find out more about the kind of Mathematics, especially geometry, the house builders in fact know and what geometry is hidden in their works; in their constructions. He supposes that his interest was especially aroused by the fact that these traditional house builders did not have any formal education.

It is expected that the Mathematics hidden in traditional house building would not be only related to geometry. In his opinion the geometrical component in this activity seems to be quite evident. However, special attention was paid to important data on other areas of mathematics.

One of his main objectives -- by looking for mathematics involved in the traditional house building -- is to reconfirm, under Mozambican conditions, that mathematical knowledge and mathematical thinking in general are not only acquired in formal schooling and the mathematical knowledge of the traditional house builders will be a small illustration of that.

By recognizing the value of people sharing in several ways, in this case by building houses, the researcher decided to do the study on this topic as a theme of Ethnomathematics. In this context Ethnomathematics can be seen, summarising Gerdes' view, as the study of the relation between Culture, Mathematics and Mathematics Education. (Gerdes, 1991). Then, as Harding-DeKam wrote, "Ethnomathematics is a term that has been coined to elucidate that everyone uses and can learn mathematics." (Harding-DeKam, 2007, p. 1)

By this study the researcher hopes to encourage more people to value traditional house building by enabling them to recognize in the so-called universal mathematics -- formal mathematics or school mathematics -- some elements that they use in their daily lives. On the other hand, by them mastering "school" or formal mathematics they can identify hidden mathematics in their activities -- that can be done indirectly through their children who attend formal school (or directly through Adults' Education Programs). This view is in agreement with one of the key processes of mathematics called connection, that means "finding links within mathematics, between mathematics and other subject areas, and for mathematics as a part of the learners' everyday experience". (Shirley, 2001, p. 86)

So, by looking to the school children our goal is to enable them to recognize in the school mathematics elements that they and/or their parents use in their daily lives, in this case by building houses or by speaking about or relate to traditional house building. Diez-Palomar, Simic & Valey in the article *'Math is Everywhere': Connecting Mathematics to Students' Lives*, describe an American experience of teaching and learning mathematics in an after-school program in which the students worked on projects that connected mathematics to their lives. They call this pedagogical approach as *Math Club* and about it they wrote that "This experience highlights the connections between mathematics and everyday life that are brought out when emphasizing culture, language, and dialogue among mathematics learners." (Diez-Palomar, Simic & Valey, 2007, p. 20). This experience bridges the students' life experiences with mathematics. (Diez-Palomar, Simic & Valey, 2007, p. 24)

For this study it is important to realize that due to the civil war in Mozambique (1976 - 1992), so many people moved from the rural areas towards towns or even from one place to another in the country side or rural areas. They started to build houses in towns or in other regions of the country side. Most of them were small *huts* and in some cases, houses built with non-traditional material. The building process, orientation, the forms, etc. of houses built in this way will not be analyzed in this study.

2.2 Analysis of current mathematics text books

The researcher found, a third complementary group of reasons by analyzing some mathematics text books used in Mozambican primary schools. Situations found in these mathematics text books led one to think that the traditional houses, even as mere objects (shapes), could be used at the very least as geometrical examples. So, before any field research the text books gave one a scant idea that there is space in the primary school mathematics (grades 1, 2 and 3) where *possible* geometry involved in traditional house building could be incorporated and, consequently, that the geometry involved in the traditional house building could be incorporated in mathematics Teacher Education.

First, two comments about two situations found in the first volume of the school book "Matemática 1^a classe, Vol. I e II" -- *Mathematics 1st grade*, Vol. I and II -- of the collection EU VOU À ESCOLA (*"I GO TO SCHOOL"*, INDE, 1982) will be presented.

1st situation: Right on page 3 (INDE, 1982, p. 3) appears a drawing of two two-sided roof houses where the heights are compared, but both houses are brick-built (Fig. 2.1).

Considering that the majority of our children have peasantry origin (rural origin), and knowing that there are situations in which even the schools are built with local materials (traditionally built), one could compare the heights of traditional houses. Or the height of one traditional and the other one brick-built. The researcher is convinced that only in that way can the child feel that after all he lives in a house and not in a *hut. The National Statistics of 1997 points that the majority of the dwellings, ca. 85,8%, in Mozambique are* *traditional houses.* (Instituto Nacional de Estatística - INE, 2001).

Larson and Larson (1984, p. 14) comment on traditional house building: “For the household itself, in the self subsistence economy, the traditional building methods are of great importance. The necessary building materials can be collected ... around the village ...”

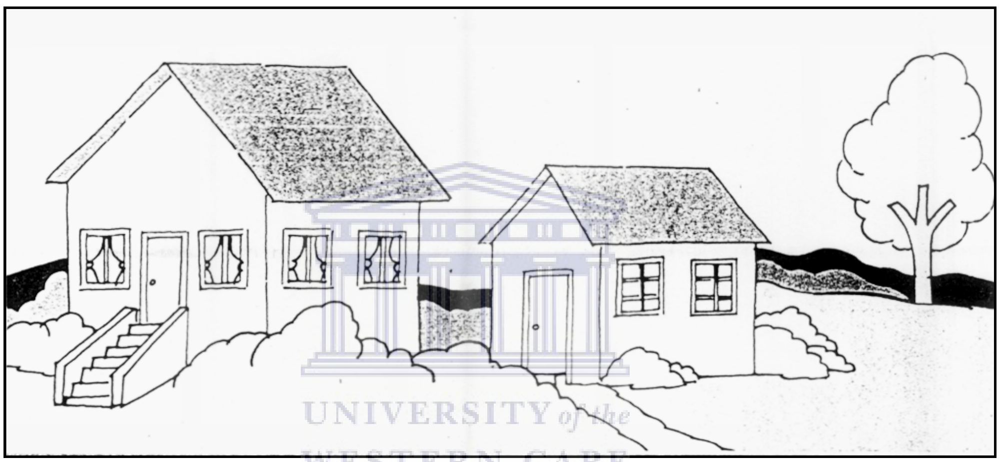


Fig. 2.1
In INDE (1982, p. 3)

2nd situation: On pages 14 and 20 (INDE, 1982) scenes are represented in which, among others, appear *mortars* — therefore, a typical Mozambican rural scene. However, the houses in the second plan are once more, brick-built houses of two-sided roofs. (See Fig. 2.2 and Fig. 2.3).

Mortars are instruments used to transform grains or cereals into flour, in rural areas.

Fig. 2.2

In INDE (1982, p. 14)

Fig. 2.3
In INDE (1982, p. 20)

Now the researcher will present, from 1st to the 3rd grades, the general objectives of the geometry syllabus from each grade, in which examples of the geometry related to the traditional house building he thinks “a priori” can be used and, whenever possible, to present what is not used at the moment in Mozambican geometry lessons.

By taking examples from the text books and not limiting his observations to analyzing the geometrical syllabus, would the researcher in no way like to consider the actual text books as the primary sources, but these are the books which Mozambique has and which must be an important reference, when one speaks about the Mozambican National System of Education in the last 19 to 20 years. Many Primary School Teachers were educated having in mind the use of these text books in their future jobs at school. The (first) National System of Education in Mozambique was introduced gradually, starting in 1983 with the 1^{st} grade.

Table 2.1: Sketch of the Mozambican National System of Education, General Education

Levels		Sub-levels	Grades	Ages	Type of Teacher
1	Primary	Pre-school	Kindergarten	under 6	
		first degree	1, 2, 3, 4, 5	7-11 years	all-subject teacher
		2^{nd} degree	6 and 7	12-13 years	subject teacher
2	Secondary	first cycle	8, 9, 10	14-16	subject teacher
		second cycle	11 and 12	17-18	subject teacher
3	Tertiary	Graduate to Licenciatura *(3 to 5-years university courses)*		19 - 24 years-old	

Apart from the General Education, the Mozambican National System of Education includes the subsystems of Technical Education (starting after grade 7) and Adults' Education.

Teacher education occurs at three levels: (**i**) a three-years course after grade 7; (**ii**) a two-years course after grade 10; and (**iii**) a three- to five-years course at university level, after grade 12. There is also a two-years course for professional adults' educators, after grade 7.

Starting in 2004, the Primary Education was divided in 3 cycles, viz.:

1st(grades 1 and 2); **2**nd(grades 3-5) and **3**rd(grades 6 and 7), and a new curriculum for the Basic Education (from 1st to 7th grades) will be introduced gradually.

The Geometry of the 1st grade (Secção de Matemática-INDE (Editor), 1985, p 25)

Objectives:

At the end of the unit, the pupils must:

- identify the rectangle, the circle and the triangle;
- identify the square as a rectangle with all sides equal;
- identify points, curved lines and straight lines and segments of straight lines;
- compare lengths of concrete objects and of segments of straight lines, using the expressions "is longer than", "is not as long as", "is shorter than", "has the same length"
- measure the length using a ruler of 20 cm;
- draw segments of straight lines.

In the introduction of the study of the rectangle (INDE, 1982, p. 38) appears no figure of a house. The researcher asks the questions:

Which other objects of real life does the teacher use, in order to give examples of rectangle, apart from the examples presented in the book? Does the teacher speak about the base of a certain type of house?

On page 43 (INDE, 1982, p. 43) some exercises are given in which pupils have to complete a rectangle.

Which comments does the teacher make after that? Does he/she speak about the job and the knowledge of the house builders?

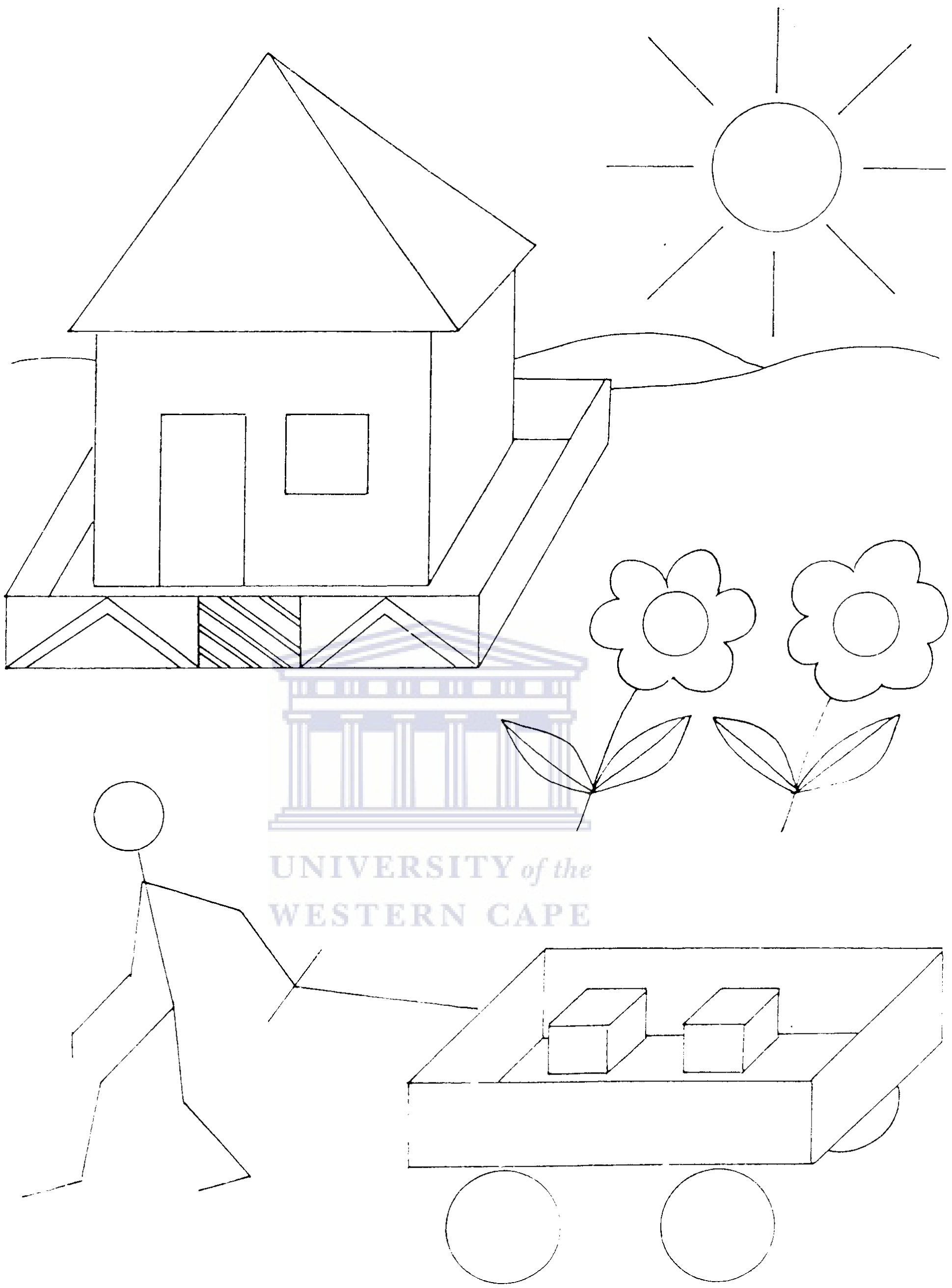


Fig. 2.4 (In INDE (1982, p. 61))

In the picture presented (INDE, 1982, p. 61) one can recognize a house. *Is the teacher sufficiently aware that he/she would tell the pupils that also in the rural areas can one find houses of this model, with rectangular base an four-*

sided roof? (Fig. 2.4).

On page 40 (INDE, 1982) the notions of triangle and circle are introduced. But, it is on that page where the pictures of houses with rectangular base appear, that had actually to appear in the introduction of rectangle on page 38. However, on the same page 40 (INDE, 1982) appear images of tents with some triangular faces -- and tents are not familiar objects for the majority of the Mozambican pupils (Fig. 2.5), maybe only related to emergencies like floods.

For the introduction of the concept of circle the book makes use of the shape of the bicycle wheels and *cross-sections* on tree trunks (Fig. 2.5). One could, giving examples of real life, make reference to the base of certain houses.

On pages 2 and 5 of the text book (INDE, 1983a) appear drawings of traditional houses -- they have rectangular base and four-sided roofs. *Does the teacher make use of the figure to review the concepts of rectangle and triangle?*

In that case both figures appear in the context of arithmetic. (Figures 2.6 and 2.7). The exercise related to the figure 2.6 consists on filling the squares with numbers after counting the elements of the same type.

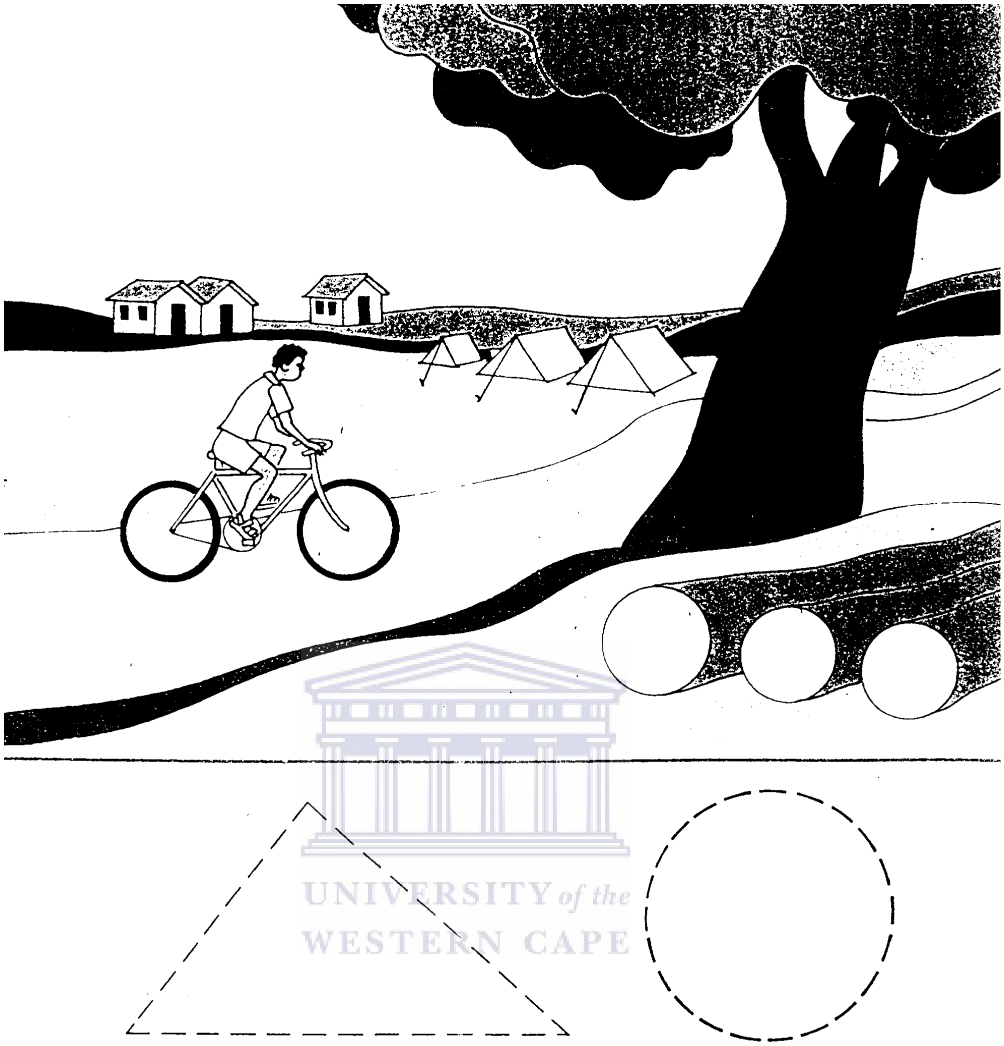


Fig. 2.5

In (INDE, 1982, p. 40)

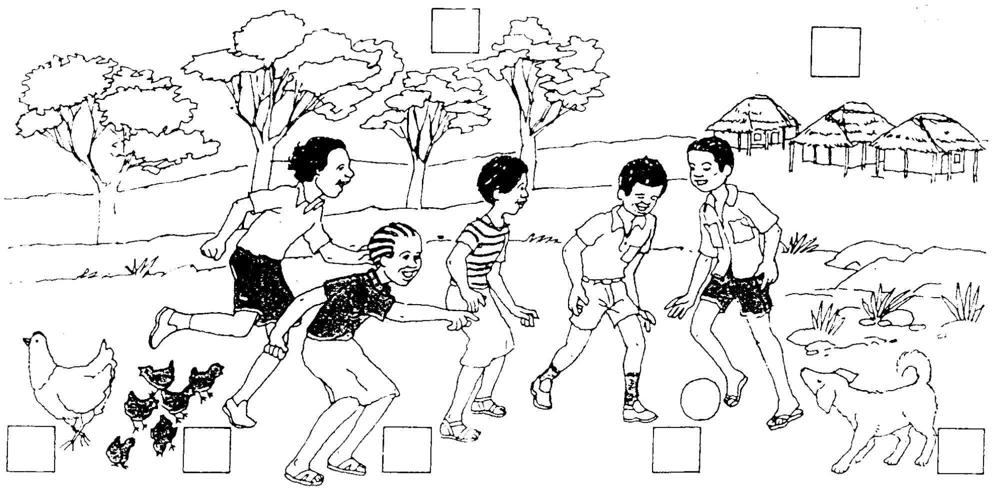


Fig. 2.6

In (INDE, 1983a, p. 2)

On page 45 (INDE, 1983a, p. 45) there are exercises on measuring the sides of the rectangle with a ruler of 20 cm. The researcher asks again: *Is during these measurements any reference made to the floor of the classroom, to the base of a type of house, etc.?*

The opinion of the researcher is that the teacher has to make reference to, specially, houses with circular base, which many people said are disappearing slowly. In fact in books they appear out of geometrical contexts. The teacher should highlight these type of houses so that the pupil of the rural area see it, not as a simple drawing in the book, but that the pupil can recognize in it his/her own house or the house of the neighbour, and that the pupil who was born and grew up in town recognizes in the TV images, for example, a house, even if very different from his/her house, but not a simply *hut.* Here one can speak again on or about connections.

Fig. 2.7

In (INDE, 1983a, p. 5)

The Geometry of the 2nd grade (ISP-Beira (Editor), 1993, pp. 9-12)

Objectives:

At the end of the study of Geometry the pupils must be able to:

- locate objects in the interior, outside and on the border of real spaces;
- identify parallel straight lines and segments of straight lines, perpendicular straight lines and segments of straight lines in real objects and in geometrical figures;
- identify right angles in real objects and in geometrical figures;
- identify sides and vertices in angles, triangles and rectangles;
- indicate important properties of the rectangle and square;

- draw straight lines through points, cutting other straight lines;
- draw parallel and perpendicular straight lines on *graph paper* pad;
- construct a triangle given the vertices;
- construct squares and rectangles on *graph paper* pad;
- identify the *geometrical solids* block, cylinder and sphere.
- identify faces and edges in the paving stones (block) and know the relations between them;
- construct blocks and cubes going from its plan and with other materials.

The official book for the 2^{nd} grade in Mozambique (at the time of this study) was "Matemática 2^{a} classe" -- *Mathematics 2^{nd} grade* -- of the collection EU GOSTO DE MATEMÁTICA. (*"I LIKE MATHEMATICS"*) - (INDE (Editor), 1984a).

This book has right on the cover the figure of a traditional house, with rectangular base and four-sided roof. The first lesson of Geometry in this book (INDE (Editor), 1984a) appears on page 12, with drawings of two buildings:

a) a school with rectangular base and two-sided roof, brick-built;

b) a traditional house with circular base. (Fig. 2.8)

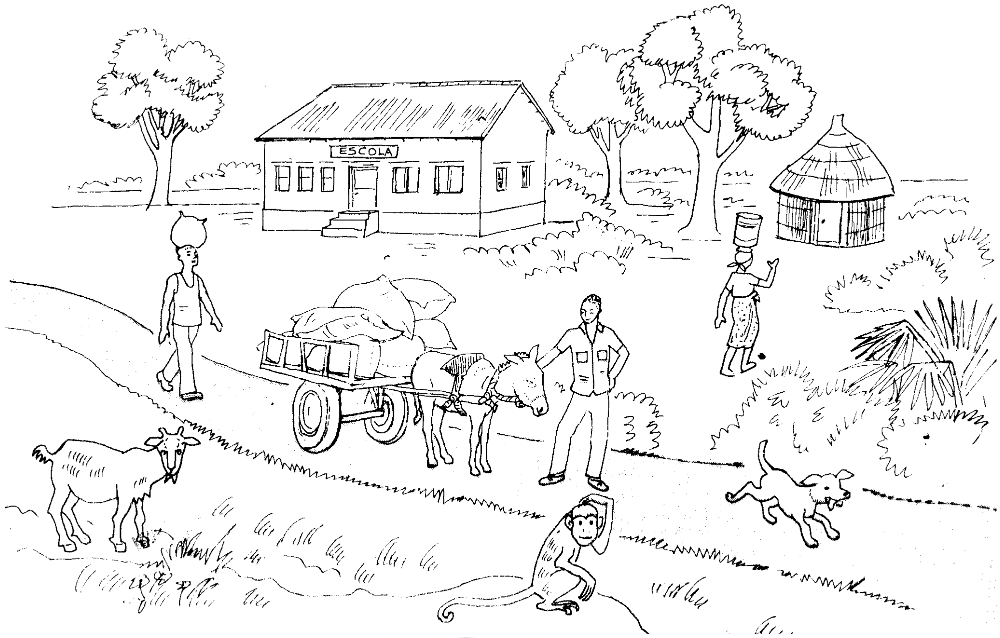


Fig. 2.8

In (INDE (Editor), 1984a, p. 12)

That could be a very good opportunity to review the notion of rectangle (the base of the school, the door, the windows, the side of the roof, etc.) using the school building and the animal cart; and to review the notions of circle using the house of circular base, the car wheels and the water pail.

On page 19 (INDE (Editor), 1984a, p. 19) there are houses with rectangular and circular bases and rectangular fields -- also one has a circular cow-enclosure. But, the lesson related to this page gives no attention to the geometrical shapes, so the objective of this lesson is only that the pupil indicates points or objects that are situated in the interior, exterior and on the border of geometrical spaces. (Fig. 2.9a and 2.9b)

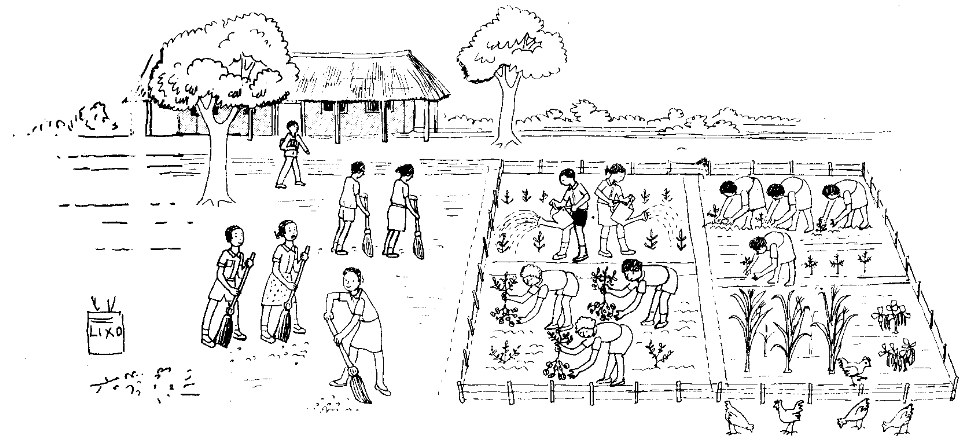


Fig. 2.9a

In (INDE (Editor), 1984a, p. 19)

Fig. 2.9b

In INDE (Editor) (1984a, p. 19)

On page 42 (INDE (Editor), 1984a), lesson about straight lines and segments of straight lines, one makes use, **for the first time in this book**, of part of a construction of a house to speak about sticks which cut each other and parallel sticks -- examples from real life about the notions of parallel straight lines and cutting segments of straight lines, which were introduced recently. But, the used picture has, however, the bad luck to be related to a brick-built house, which can give the false idea that only brick-built constructions can produce perpendicular sticks. (Fig. 2.10)

Fig. 2.10

In (INDE (Editor), 1984a, p. 42)

On page 54 (INDE (Editor), 1984a) there are figures which contain right angles. On the same page one gives the instructions to the pupils in order to identify more right angles in the surroundings.

Which explanations does a teacher give in order to come to the conclusion that a given stick makes or does not make a right angle with the floor? At that point the teacher could speak about the right angles in the corners of the classroom, in the corners of many houses, precisely the houses with rectangular or square base, whether it is a brick-built or a traditional house.

On page 65 (INDE (Editor), 1984a), regarding perpendicular straight lines, the given real life example is a perpendicularity between sticks of an enclosure for kids. In the view of the researcher, it must have an exercise instructing the pupil to look around for perpendicular real objects.

On page 72 (INDE (Editor), 1984a), by checking the measurements of a rectangle in real life objects one sees the top of a table and a school sports field. One could point to more real objects, like the classroom floor, the base of the type of houses, etc. And on page 76 (INDE (Editor), 1984a), where the measurements of the sides of the square are considered, no one real example is given.

Finishing the study of the books of 2nd grade the researcher would like to *say that in the exercise books volumes I and II* (INDE, 1983b and 1983c) *appear some drawings of houses both of rectangular base and of circular base, but they do not enter directly in the exercises. One cannot find, for example, tasks for measuring the length of the base or the height of the wall of a house with rectangular base and rectangular walls.*

The Geometry of the 3rd grade (ISP-Beira (Editor), 1993, pp. 13-17)

Objectives:

At the end of the study of Geometry the pupils must be able to:

- know the units millimeter and kilometer, gram and ton, knowing the ratio with the units learned before and make measurements;
- indicate his/her own position in the space, others' position with reference to him/her-self and vice-versa and the position of objects amongst them;
- identify and draw segments, parallel and perpendicular straight lines using a ruler and a paper-square *(a right angle made of paper, a Mozambican(?) innovation)*;
- identify and classify parallelograms using the most important properties;
- draw circles and know the notions of centre and radius;
- identify and describe geometrical solids including the cone and pyramid, starting from observation of real objects, from drawings or from given description.

The official book for the 3rd grade in Mozambique (at the time of this study) is "Matemática 3ª classe" -- *Mathematics 3rd grade* -- of the collection EU GOSTO DE MATEMÁTICA. (*"I LIKE MATHEMATICS"*) (INDE (Editor), 1984b) and has on the cover pupils using a wooden square to draw perpendicular lines on the ground and other pupils drawing a circle using two sticks and rope (Fig. 2.11).

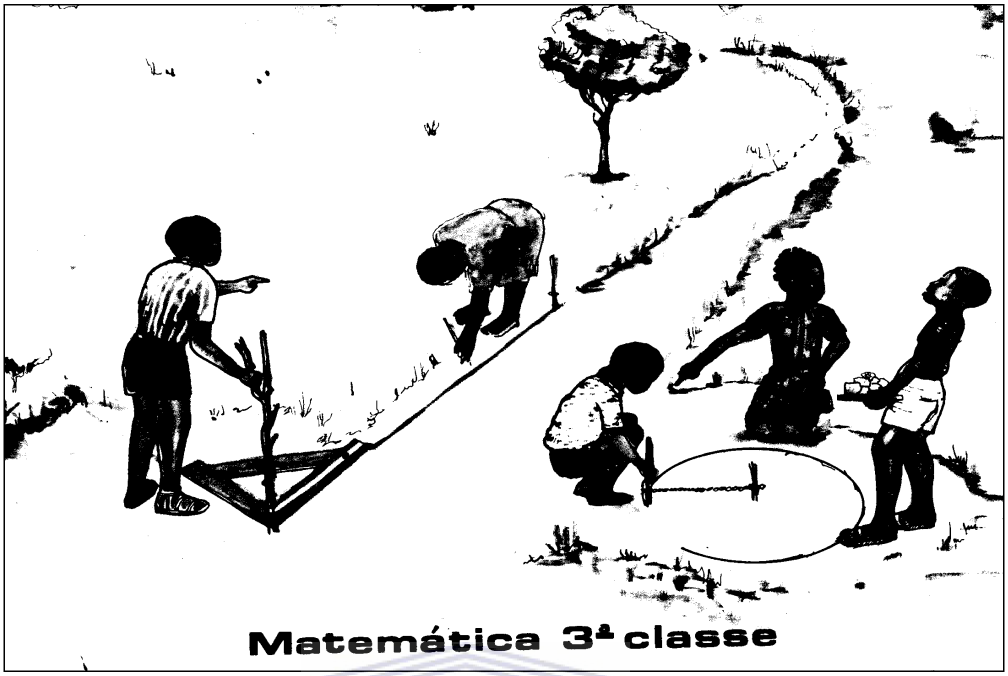


Fig. 2.11
In (INDE (Editor), 1984b, cover)

On page 39 of this book (INDE (Editor), 1984b) we have the following picture (Fig. 2.12).

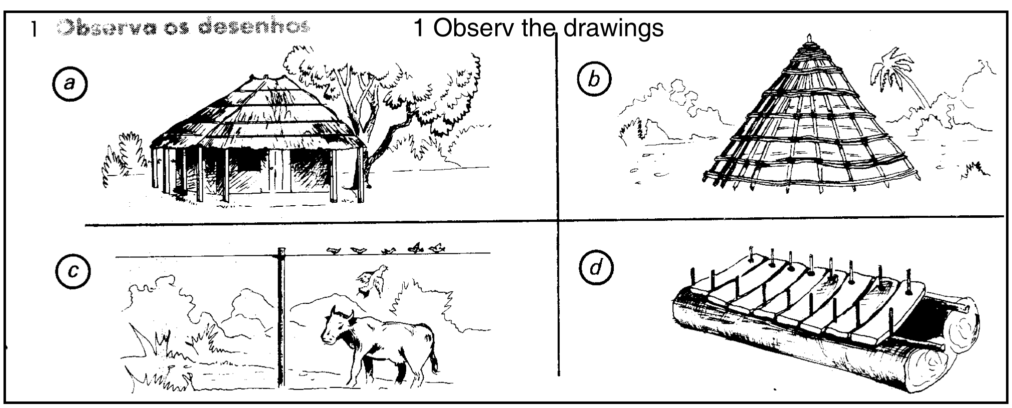


Fig. 2.12
In INDE (Editor) (1984b, p. 39)

The exercises (in the text book) related to this picture are to indicate the letters corresponding to drawings in which (1) segments of straight lines are parallel and (2) segments of straight lines are perpendicular.

On the drawing “a” we have parallel pillars and parallel *balilo* (battens) on the roof.

On the drawing “b” we see the draft of a roof from a house of circular base.

It is clear that at the 3rd grade level there are no parallel segments neither perpendicular straight lines as shown in this drawing -- in 3rd grade one deals only with plane geometry. But at other levels of abstraction one can see concentric and parallel circles in space which in the non-Euclidean geometry can be seen as examples of parallel straight lines, where the circles have no points in common even if belonging to the same “plane”, the surface of the cone. One has to remember that on the picture above the researcher is more interested in examples related to traditional house building.

On page 44 (INDE, 1984b) one has the example of Mr. Magaia, who is constructing the rectangular base of a house using a thread and a set square. (Fig. 2.13) The pupils are asked to observe and to try during their refreshment intervals between class sessions.

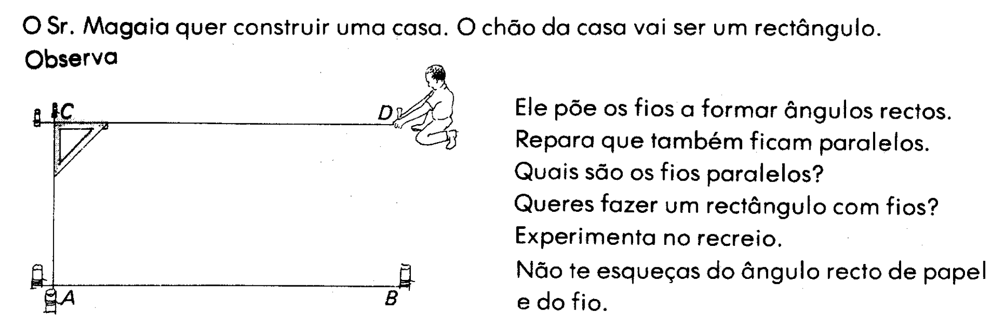


Fig. 2.13
In (INDE (Editor), 1984b, p. 44)

Free translation on the picture: “Mr. Magaia will construct a house. The ground of the house will be a rectangle. Look.”

“He forms right angles with the strings. Look that they also become parallel. Which are the parallel strings?

Do you want to make a rectangle with strings? Try it during the interval.

Don't forget the *paper-square* and the string." (INDE (Editor), 1984b, p. 44)

What a shame that on the text one says already that the obtained angles are right angles and that the threads (strings) become parallel. One could allow the pupil to come to this conclusion, by themselves or in small groups.

On page 70 (INDE (Editor), 1984b) one finds figures for the revision of the notions of circle, centre and radius (Fig. 2.14) but, in contrary to the suggestion on the cover of the book, there is no example of the method used by the house builder or by the gardener for constructing a circle with sticks and rope (Fig. 2.11).

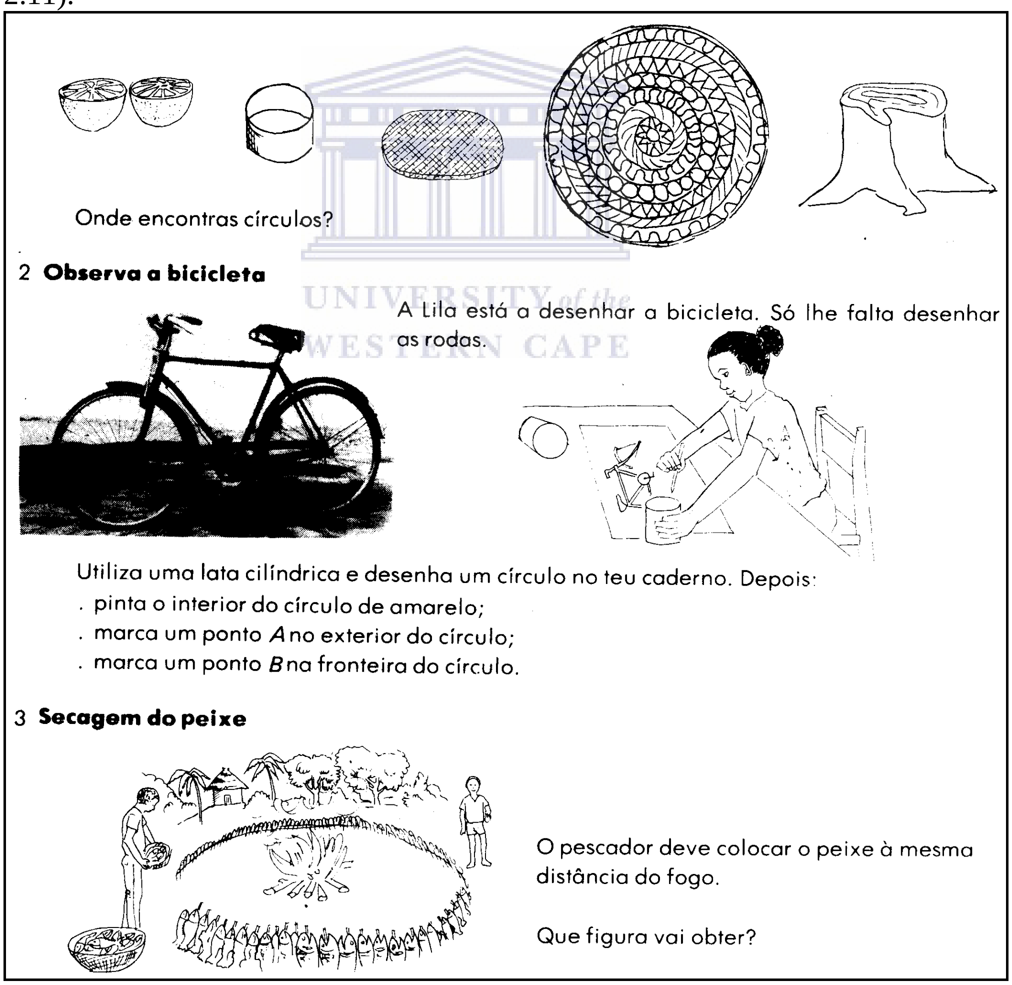


Fig. 2.14

In (INDE (Editor), 1984b, p. 70)

(A Germany mathematician said in 1989 that the use of a paper-square was unique in the world, according to his knowledge. Mozambique developed sash a geometrical instrument for regions were one can not find set square.)

On the top of the previous picture (Fig. 2.14) we have the question:

"Where can you find circles?"

Then we have:

"**2 Look to the bicycle**"

"Lila is drawing a bicycle. Only the wheels are missing in the drawing."

"Use a cylindrical can to draw a circle in your exercise book. Then:

. paint the interior of the circle in yellow;

. mark a point A on the exterior of the circle;

. mark a point B on the circle line."

"**3 Fish drying**

The fisher-man must put the fish at the same distance from the fire.

Which geometrical shape will he obtain?" (INDE (Editor), 1984b, p. 70)

Fortunately this method is rescued on page 79, where one said that the teacher is going to teach the pupils to construct a circular flower bed. (Fig. 2.15).

Fig, 2.15
In (INDE (Editor), 1984b, p. 79)

"The pupils will construct a flower bed with a circular shape.
The teacher teaches how to draw the circle.
Look how she does it." (INDE (Editor), 1984b, p. 79).

On page 89, the lesson about geometrical solids, roof formats and other objects of Mozambican rural reality are used as concrete examples of geometrical forms (3-dimensional shapes) like cone and pyramid. (Fig. 2.16).

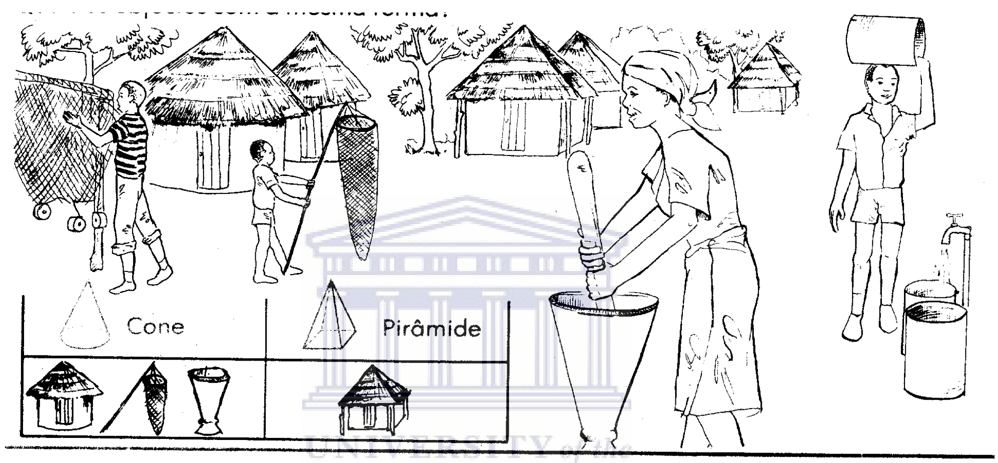


Fig. 2.16
In (INDE (Editor), 1984b, p. 89)

Further, in the lesson about cylinder, the book (INDE (Editor), 1984b, p. 108) refers to the house which will be constructed by Mr. Bila after drawing the circular base. (Fig. 2.17).

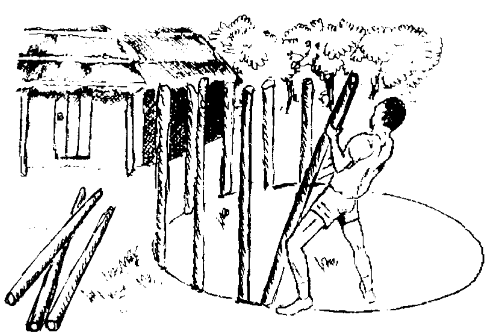


Fig. 2.17
In (INDE (Editor), 1984b, p 108)

But the researcher is sure that the geometry involved in the traditional house building which can be incorporated in the school mathematics must not be reduced only to geometrical shapes and forms as showed in the figures 2.16 and 2.17.

Still looking at mathematics school books of the primary school the researcher found an exercise in the book of the 4th grade. (Fig. 2.18) (INDE, 1985, p. 27).

Fig. 2.18
In (INDE, 1985, p 27)

The exercise related to this figure points that John has 56 sticks to construct a small circular based house. Further, one is asked about how many bundles of ten sticks can be formed and how many sticks will remain. So a question about arithmetic.

The researcher's question is if this problem is real. *Can one with 56 sticks construct a small house?*

In the same school book (INDE, 1985, p. 64), of the 4th grade, the researcher found a reference to the *first method* found during the pilot study for constructing the rectangular base of a house (Fig. 2.19). This method will be classified as the *first method* in the thesis -- more details about this method in chapter 6, section 6.1.2a.

However, the use of two scaled or calibrated ropes to compare the lengths of the diagonals -- look carefully to the figure -- can be a demonstration that in this case, different from what the researcher found in the research field, this method is related to techniques used when one works with paper and pencil. In the practice of the house builder it is enough to work with one piece of rope (not necessarily scaled) to compare the diagonals. That will not mean that the Mozambican countrymen/-women and house builders don't use scaled or calibrated rope for measurements. They use scaled rope, for example, to determine the dimensions of a field in order to compare with another field or to calculate the probable quantity of a harvest. Nevertheless, by measuring diagonals in order to construct a rectangle it is not important to know how many centimetres or metres, inches or feet are the diagonals long, what is important is that they may have the same length -- so one can do that without scaled rope.

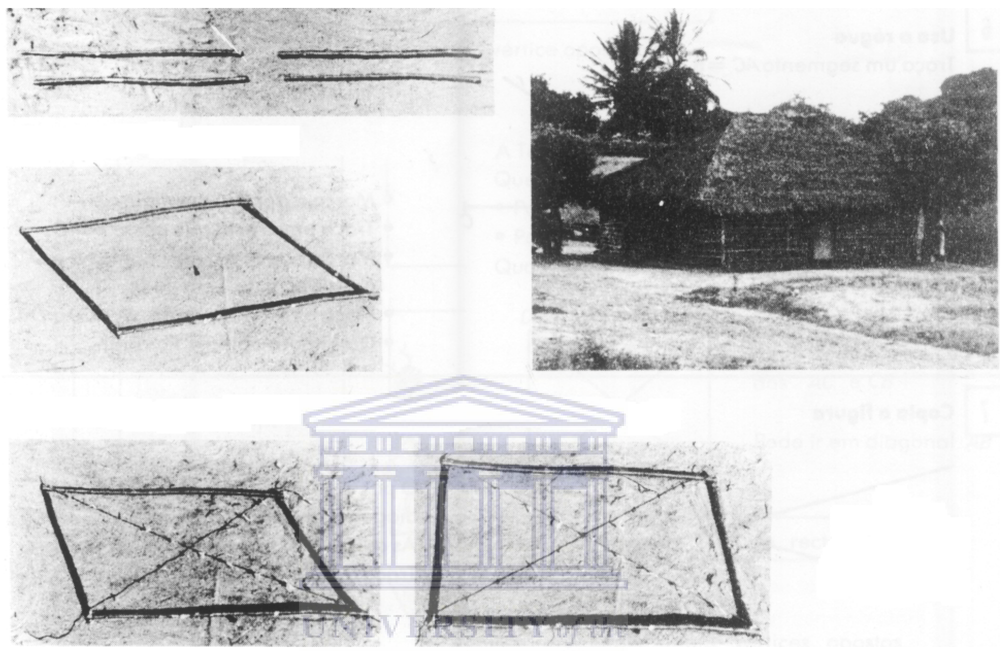


Fig. 2.19
In (INDE, 1985, p. 64)

So, with these reflections around the mathematics school books of the grades 1, 2, 3 and other reflections the researcher came again to the two research questions:

1. *What mathematics is involved in the traditional house building?*
2. *How can this knowledge be incorporated in Mathematics Education in Mozambique?*

The possibilities to incorporate geometrical elements related to traditional house building in Mathematics Education in Mozambique are given, since the syllabus and the methodological orientations are not very strict. For example, in the introduction of the teachers manual for the 3rd grade it is written that *"Once more the teacher is reminded that this manual is a basis for the work, but must not substitute the self-study and the reflection at the teacher's level and at the level of each school. The guidelines in it must be enriched and adapted to the reality of each school and each class"*. (INDE/NELE (Editor), 1985, Vol II, p. 6).

Apart from that, the new primary school curriculum to be introduced gradually, starting in 2004, in grades 1, 3 and 6, reserves ca. 20% of the time for syllabus related to local reality. So, the teacher education has to prepare the student teachers for that new situation. To make a contribution for that, through the mathematics involved in traditional house building, constitutes a big motivation for this study.

The fulfilment of the thesis, being the researcher (and) a part-time student, took a long period of time, so that presently (after the year 2003) one is editing new mathematics text books. However, the teachers are more familiarised with the text books analysed in this section.

Be sides the new text books, adopted already by the Ministry of Education and Culture, were not jet formally evaluated by external experts. So, one doesn't know if they are there to stay or not. However, the new text book of the grade 4 shoes a picture of a round house, taking the roof format as a real example of a cone. It has also pictures with the Egyptian Pyramids and a roof of a traditional square based house as real life examples for pyramids. (Murimo et al, 2004, pp 64-65).

The innovation is that, whereas in figure 2.16 one has drawings, in the new text book one shoes coloured photographs.

2.3 Motivation found in literature on African house building

The researcher found motivation in the earlier literature on African house building too. For example, about the Bantu traditional house builders Frobenius wrote:

> *Wir müssen die Ärmlichkeit der Mittel und die Unzulänglichkeit des Handwerkszeuges wohl im Auge behalten, wenn wir die Banten betrachten, welche damit erzeugt worden sind und wir werden staunen müssen über die Geschiklichkeit, Intelligenz und Vorstellungsgabe der Erbauer.* (Frobenius, 1894, p. 8).

(Free translation: "When we contemplate the Bantu, we must keep in mind the poverty of the means and the lack of the implements/tools with which they produce, and we have to be astonished about the ability/skills, intelligence and imagination of the builders."). And Denyer wrote that

> The myth of darkest Africa is persistent and there are still many people who find it difficult to accept that the traditional buildings of the continent merit more than passing consideration. One only has to consider for a moment the vocabulary used to refer to them (including such basic words as 'mud' and 'hut', which in English have such derogatory overtones) to realize that even for those who know and respect other aspects of African culture it is hard to avoid being drawn into a web of selective and distorted perceptions (Denyer, 1978, p. 1).

These two observations gave to the researcher an additional interest in doing research on traditional house building in Mozambique, an African Country.

2.4 Justification of the relevance of the research

Recently two Mozambican Mathematics Educators finished their doctoral theses looking at cultural aspects: (1) Ismael (2002) and (2) Cherinda (2002) at the University of the Witwatersrand, in South Africa.

With the title *An Ethnomathematical Study of Tchadji — About a Mancala Type Boardgame Played in Mozambique and Possibilities for it's Use in Mathematics Education*, Ismael studied a cultural game played at Ilha de Moçambique, a Mozambican Island.

Cherinda completed his thesis with the title *The Use of Cultural activity in the Teaching and learning of Mathematics: Exploring twill weaving with a weaving board in Mozambican Classrooms*. Cherinda's thesis is about a study of the use of plain and twill weaving in the teaching of mathematics -- especially, sequences -- in Mozambican classrooms. Cherinda was moved by the idea that "For the success of education in Mozambique, particularly in mathematics, there is a need to develop a curriculum embedded in the learner's socio-cultural environment." (Cherinda, 2002, p. ii)

Mosimege, a South African researcher, submitted his doctoral thesis in the year 2000, at the University of the Western Cape, with the title *Exploration of the Games of Malepa and Morabaraba in South African Secondary School Mathematics Education* in which he studies some culturally specific and related games. (Mosimege, 2000)

Staats, in her article *The case for rich contexts in ethnomathematics lessons*, presenting an approach for integrating ethnomathematics into undergraduate classes in Alaska, USA, called it a 'socially contextualized' approach, suggests that *(i)*"... we must take a nontraditional perspective on how we treat the context of an application in class, and that *(ii)* we must make the context of the application intellectually more active, so that students engage issues that are significant, socially and anthropologically" (Staats, 2006, p. 42)

Ismael, Cherinda and the researcher are in agreement that "the role of teachers in implementing ethnomathematics in the school is seen to be crucial. Before, for implementation to take place, it is important that the teachers themselves accept it". (Ismael, 2002, p. 266)

As one can see, the thesis is not an isolated research in Mozambican context -- in Mozambican Teacher Education's Programme. This statement gave to the researcher an extra desire in completing his study.

One may not forget the several studies done by Gerdes linking Mathematics, Culture and Mathematics Education in Mozambique and in Africa.

In next chapter the researcher will present the theory in which this study is based on -- Ethnomathematics.

3. Theoretical Framework

The theoretical basis of this study is Ethnomathematics, a relatively new field of research in Mathematics and Mathematics Education.

3.1 What is Ethnomathematics? Some ideas about Ethnomathematics.

There exist several definitions and attempts of definitions for Ethnomathematics. In Wikipedia, the free encyclopedia, 2007, one can find that

> **Ethnomathematics** is the study of the relationship between mathematics and culture. It refers to a broad cluster of ideas ranging from distinct *numerical and mathematical systems* to multicultural mathematics education. The goal of ethnomathematics is to contribute both to the understanding of culture and the understanding of mathematics, but mainly to appreciating the connections between the two.” (Wikipedia, 2007, p. 1 – *italic by the researcher.)*

In the thesis the researcher will deal with those definitions which are in agreement with the understanding of Ethnomathematics that is used in Mozambique, emphasizing definitions by D’Ambrosio and by Gerdes. According to D'Ambrosio -- who is regarded as the intellectual father of ethnomathematics -- Ethnomathematics means "the art or technique of explanations, of knowledge, of understanding in different cultural contexts" (D'Ambrosio, 1990, p. 81). Broadly speaking, Ethnomathematics can also be viewed as the study of the relation among culture, mathematics and mathematics Education – resuming some ideas by Gerdes.

D’Ambrosio writes that

> culture manifests itself through jargons, codes, myths, symbols, utopias, and ways of reasoning and inferring. Associated with these we have practices such as ciphering and counting, measuring, classifying, ordering, inferring, modeling and so on, which constitute ethnomathematics (D'Ambrosio, 1991, p. 20).

For Gerdes Ethnomathematics is a relatively new field of interest which may be defined as "the cultural anthropology of mathematics and mathematical education", i.e., one field of interest "that lies at the confluence of mathematics and cultural anthropology" (Gerdes, 1996, p. 909). Similarly D'Ambrosio writes that "Our subject lies on the borderline between the history of mathematics and cultural anthropology." (D'Ambrosio, 1991, p. 15). D'Ambrosio also adverts the readers that Ethnomathematics is often confused with ethnic-mathematics. (D'Ambrisio, 2006, p. 1). D'Ambrosio devides the word ethnomathematics in *ethno+mathema+tics(techné),* (2006, p. 1), where ethno does not mean ethnic, as one will see later. Ascher (1991) presents a definition of Ethnomathematics writing that "the study of mathematical ideas of traditional peoples is part of a new endeavor called ethnomathematics", (Ascher, 1991, p. 1) and explains that traditional people are those who live in traditional or small-scale cultures -- people who have generally been excluded from discussions of mathematics. (1991, p. 1). About this last idea, the researcher thinks that traditional people have not necessarily lived in small-scale cultures, at least looking to the Mozambican reality.

Borba (1997) gives also an interesting definition of Ethnomathematics. He begins saying that each language expresses a way of knowing developed by a group of human beings, mathematics being one way of knowing, and further explains that: "Mathematical knowledge expressed in the language code of a given sociocultural group is called ‘ethnomathematics’.” (Borba, 1997, p. 265). Borba compares ethnomathematics with a forest, writing that:

> A forest might be a better image of the whole set of ethnomathematics, in which each tree would be considered as a different expression of ethnomathematics, socioculturally producted (Borba, 1997, p. 267).

While for some proponents Ethnomathematics is simply a vehicle to express their resistance against the eurocentrism of mathematics and its history, some other would see it as a way of unearthing the mathematical contributions of oppressed peoples in different parts of the globe. This latter view is the one that would form the basis of the theoretical perspectives the researcher would use to inform his study -- maybe influenced by the fact that the Mozambicans belong to the former oppressed peoples. So, for example, the following ten concepts and phrases were studied in order to ensure that a coherent thread spans the research study to be undertaken: 'sociomathematics', 'spontaneous mathematics', 'oral mathematics', 'non-standard mathematics', 'oppressed mathematics', 'hidden or frozen mathematics', 'folk mathematics', 'psychological blockage', ‘academic mathematics' and 'indigenous mathematics'.

Given the relative newness of research within the context of ethnomathematics, the researcher’s approach would be in concert with Paulus Gerdes´s view of ethnomathematics, viz., to consider provisionally an ethnomathematical accent in research and in mathematics education, or an ethnomathematical movement (Gerdes, 1995a, pp. 12-19). This approach will allow for a rich interplay between theory and practice, and, indeed, may lead to theory-building as a possible spin-off of the research. So, an approach that conciliate the unearthing of mathematical contributions of oppressed people with ways of making the mathematics education more concrete, more familiar, in this case using traditional house building as example.

Speaking about ethnomathematical movement Gerdes names the researchers involved in the movement as ethnomathematicians and indicates some characteristics of the ethnomatematical movement in that ethnomatematicians: (1) Adopt a broad concept of mathematics including counting, locating, measuring, playing, explaining, etc, (2) Emphasize and analyze the influences of socio-cultural factors on the teaching, learning and development of mathematics, (3) Argue that the techniques and truths of mathematics are a cultural product and stress that every culture and every subculture develop their own particular forms of mathematics and so the development of mathematics is not unilinear, (4) Emphasize that the school mathematics of the transplanted, imported curriculum is apparently alien to the cultural traditions of Africa, Asia, and South America, even if in reality. However, a great part of the contents of school mathematics is of African and Asian origin, that was expropriated in the process of colonization, (5) Look for cultural elements which have survived colonialism and try to reconstruct the original mathematical and other scientific modes of thinking, concepts, and principles; and (6) Try to develop ways of incorporating mathematical traditions and activities in people's daily life into the curriculum and to favour a socio-critical view and interpretation of mathematics education which enables students to reflect on the realities in which they live, and empowers them to develop and use mathematics in an emancipatory way (cf., Gerdes, 1996, pp. 917-918).

3.2 Ethnomathematics, Mathematics Education and Teacher Education

According to Gerdes "The concept of ethnomathematics is relatively new among mathematicians and teachers of mathematics." (Gerdes, 1995a, p.12). Relating Ethnomathematics and Mathematics Education the researcher can say that many people are convinced that it is not at school that one would have his/her first encounter with mathematical ideas. Knijnik (1997), reporting on her research with landless Brazilian rural workers, broaches the concept ethnomathematical approach in mathematical education. And explains that she uses

> the expression *ethnomathematical approach* to designate the investigation of the traditions, practices, and mathematical concepts of a subordinated social group and the pedagogical work which was developed in order for the group to be able to interpret and decode its knowledge; to acquire the knowledge produced by *academic mathematicians*; and to establish comparisons between its knowledge and academic knowledge, thus being able to analyze the power relations in the use of both these kinds of knowledge (Knijnik, 1997, p. 405 -- italic by the researcher).

D'Ambrosio (1991, p. 18) distinguished between (•)*academic mathematics*, that for him is the mathematics which is taught and learned in the schools, with ethnomathematics, which he described as the mathematics

> which is practiced among identifiable cultural groups, such as national-tribal societies, labour groups, children of a certain age bracket, professional classes, and so on (D'Ambrosio, 1991, p.18).

Gerdes writes that D'Ambrosio

> proposed an ethnomathematical program as a 'methodology to track and analyze the process of generation, transmission, diffusion and institutionalization of (mathematical) knowledge' in diverse cultural systems (Gerdes, 1996, p. 912).

Borba (1997) says that the notion of ethnomathematics has clear implications for education and argues that:

> If different people produce different kinds of mathematics, then it is not possible to think about education as being a uniform process to be developed in the same way for different groups. Instead mathematics education should be thought of as a process in which the starting point would be the ethnomathematics of a given group and the goal would be for the student to develop a multicultural approach to mathematics (Borba, 1997, pp. 266-267).

Fossa (2006) describing his project *Ethnomathematics and Cooperativism* in Northeast of Brazil writes that

> The teaching methodology employed rejects the traditional approach of the transmission of knowledge from the professor to the student; rather we attempt to create a true dialogue that takes the participants' prior (ethnomathematical) knowledge as the starting point and attempts to foster greater metacognitive awareness on the part of the participants. (Fossa, 2006, p. 35) and concluded that their conviction in the project have been further strengthened that the conjunction of ethnomathematics and cooperativism is a fruitful way to

approach many pedagogical and social problems that they face in the world. (Fossa, 2006, p. 36).

Gerdes summarized the essence and the objectives of Ethnomatematics writing that

> in general, ethnomathematics is the study of the interrelationship between (the) mathematics and (the) culture(s) of a given people or population group. Ethnomathematical studies in Third World countries and in Africa, in particular, look for and analyze
>
> * mathematical traditions that survived colonization and mathematical activities in people's daily life and ways to incorporate them into the curriculum;
> * culture elements that may serve as a starting point for doing and elaborating mathematics in the classroom (Gerdes, 1995a, p. 1).

The two views of ethnomathematics, by Gerdes -- the most prolific writer in ethnomathematics at the moment -- and by D'Ambrosio, are not contradictory. If they are different, the difference can consist of the fact that the "definition" by Gerdes seems to be more dynamic. Dynamic in the sense that it makes or leaves clearer the motion or movement that goes from the analysis of the cultural activity or artefact, the search for the mathematics involved, its relation to the school mathematics (curriculum) and back to the activity or artefact, and the subsequent mathematical exploration and generalization for the construction of mathematics educational approaches (new curriculum). Furthermore Gerdes (1996, p. 912) – quoting D'Ambrosio -- writes that

> an individual who is able to manage perfectly well numbers, operations, geometric forms and notions, when facing a completely new and formal approach to the same facts and needs, creates a (•)psychological blockage which grows as a barrier between different modes of numerical and geometrical thought.

This statement shows us the importance or value of Ethnomathematics in Mathematics Education.

Now the meaning of the remaining eight key-words or phrases will be presented:

- sociomathematics of Africa is defined as "the applications of mathematics in the lives of African people, and, conversely, the influence that African institutions had upon the evolution of their mathematics". (Zaslavsky, 1999, p. 7). For Gerdes "The concept of sociomathematics may be considered a forerunner of the concept of ethnomathematics. It is ethnomathematics as a discipline that studies mathematics (and mathematical education) as embedded in their cultural context -- the (development of) different forms of mathematical thinking which are proper to cultural groups, like ethnic, professional, and age groups." (Gerdes, 1995a, p. 137)
- spontaneous mathematics: each human being and each cultural group develops spontaneously certain mathematical methods. (Gerdes, 1995a, p 14);
- oral mathematics: in all human societies there exists mathematical knowledge that is transmitted orally from one generation to the next. (Gerdes, 1995a, p. 15; Carraher and others, 1982; Kane, 1987);
- opressed mathematics: in societies divided by classes, or class societies (e.g., in the countries of the 'Third World' during the colonial occupation) there exist

mathematical elements in the daily life of the populations, that are not recognized as mathematics by the dominant ideology. (Gerdes, 1995a, p. 15; Gerdes, 1982);

- non-standard mathematics: beyond the dominant standard forms of ‘academic’ and ‘school’ mathematics there develop and developed in the whole world and in each culture mathematical forms that are distinct from the established patterns. (Gerdes, 1995a, p. 15; Carraher, 1982; Gerdes, 1985; Harris, 1987);
- folk mathematics: the mathematics (although often not recognized as such) that develops in the working activity of each of the peoples may serve as a starting point in the teaching of mathematics. (Gerdes, 1995a, p. 15; Mellin-Olsen, 1986);
- indigenous mathematics: creative mathematical education that uses things that have meaning within indigenous culture as starting point. (Gerdes, 1995b, p. 6; commenting on [Gay & Cole, 1967; Lancy, 1976]);
- hidden or frozen mathematics: although, probably, the majority of mathematical knowledge of the formerly colonized people has been lost, one may try to reconstruct or ‘unfreeze’ the mathematical thinking, that is ‘hidden’ in old techniques like, e.g., that of basketmaking (Gerdes, 1995a, p. 15; Gerdes, 1982, 1985) or, in this case, that of traditional house building.

According to Gerdes “By unfreezing this frozen mathematics, by rediscovering hidden mathematics in the Mozambican culture, we show indeed that the people of Mozambique, like every other people, did mathematics,” (Gerdes, 1995a, p. 29) and, in addition he writes that, “defrosting frozen mathematics can serve as a starting point for doing and elaborating mathematics in the classroom ...” (1995a, p. 29) and concludes writing that:

> At the same time 'unfreezing frozen mathematics' forces mathematicians and philosophers to reflect on the relationship between geometrical thinking and material production, between doing mathematics and technology. Where do (early) geometrical ideas come from? (Gerdes, 1995a, p. 29).

The last question by Gerdes can be interpreted as an induction to the thinking that early geometrical ideas came from practice, from human daily activities. So, therefore, Mathematics Education has to be strongly connected to the practice, to out-of-school mathematics, to spontaneous mathematics.

Shirley, who considers ethnomathematics as a fundamental of instructional methodology, says that when ethnomathematics was proposed in the 1970s and 1980s as an area of study in mathematics education, it had the look of something new and exotic, as an add-on, a frill, or an enrichment topic, and that "the feeling was common that mathematics was mathematics, (and that usually meant mathematics was European mathematics)". (Shirley, 2001, pp. 85-86).

But, as Shirley writes, it is now at the hearth of instructional methodology and "history and culture of mathematics seemed to be little more than a frill of enrichment". (Shirley, 2001, p. 85). Shirley suggested ways of incorporating ethnomathematics in teacher education that, according to this author, could mean the broadening of the courses' contents including "worldwide history of mathematics and international and multicultural applications of mathematical content". (Shirley, 2001, p. 86)

Shirley detaches two key processes of mathematics that are more related to ethnomathematics, namely communication and connection. "Communication means students expressing their thinking and exchanging their ideas amongst themselves" and Connections "means finding links within mathematics, between mathematics and other subject areas, and for mathematics as a part of the learners' everyday experience". (Shirley, 2001, p. 86). And further writes that ethnomathematics is a key to finding those connections (p. 86). As conclusion Shirley suggests that: "it is central to a broad view of mathematics -- to demonstrate that mathematics is not the property of the West and that mathematics values -- and even requires -- the contributions of all for its continued progress", (p. 87) and emphasizes that the ethnomathematics is crucial to mathematics teacher education in order to guarantee that the above presented message can be carried to the new generations. (Shirley, 2001, p. 87).

On the use of ethnomathematics in mathematics education Powell and Frankenstein "suggest coinvestigation between students and teachers into discovering each others' ethnomathematical knowledge" and are convinced that "this will improve our teaching". (Powell and Frankenstein, 1997, p. 321)

3.3 Socio-political aspects of Ethnomathematics

About the origin of ethnomathematics, and at the same time showing that ethnomathematics is seen as vehicle to express resistance against the eurocentrism of mathematics and its history, Powell and Frankenstein comment that

> what is particularly significant about the academic discipline of ethnomathematics is that it emerged from intellectual influences of emancipatory struggles worldwide and that interest and work in the discipline has not been limited to the academy (Powell and Frankenstein, 1997, p. xi)

and also that

> many people have contributed to the emergence of ethnomathematics through their organizational and curricular efforts, thereby changing ideas and practices within the mathematics education community (Powell and Frankenstein, 1997, p. xi).

Demonstrating that the discipline of ethnomathematics has not been limited to the academy -- as said by Powell and Frankenstein -- Samora Machel, the first President of independent Mozambique, quoted by Gerdes, insinuates the need of ethno-(science)mathematics in Mozambican school curriculum by saying:

> Colonization is the greatest destroyer of culture that humanity has ever known. African society and its culture were crushed, and when they survived they were co-opted so that they could be more easily emptied of their content.
>
> This was done in two distinct ways. One was the utilization of institutions in order to support colonial exploitation ... The other was the ‘folklorizing’ of culture, its reduction to more or less pictoresque habits and costumes, to impose in their place the values of colonialism.
>
> ... Colonial education appears in this context as a process of denying the national character, alienating the Mozambican from his country and his origin and, in exacerbating his dependence on abroad, forcing him to be ashamed of his people and his culture.
>
> ... long suppressed manifestations of culture have to regain their place. (Gerdes, 1986, p. 26; Machel, 1978).

The viewpoint by Powell and Frankenstein agrees with the one by Vithal and Skovsmose when they write that “Ethnomathematics originated in the former colonies, in response to the Eurocentrism of the history of mathematics, mathematics itself and mathematics education." (Vithal and Skovsmose, 1997, p. 131).

And Gerdes (1995a) explains that

> Colonial education presented mathematics generally as something rather 'western' or 'European', as an exclusive creation of 'white men'. With the hasty curriculum transplantation - during the 1960's - from the highly industrialized nations to 'Third World' countries there continued, at least implicitly, the negation of African, Asian, America-Indian, mathematics. (Gerdes, 1995a, p. 13).

3.4 Critique of Ethnomathematics

Vithal and Skovsmose, in their critique of ethnomathematics, present four strands of ethnomathematics: (1) the one that challenges the traditional history of mathematics -- historians of mathematics are criticized, firstly, for ignoring, devaluing, distorting or marginalizing the contributions of cultures outside Europe (China, India, North Africa and Arab World) and, secondly, for only paying marginal attention to the history of mathematics in cultures that have not directly contributed to 'Western' mathematics (American Indians and sub-Saharan Africans); (2) that (which overlaps with the first) analyses the mathematics of traditional cultures, of indigenous peoples who may have been colonized but have continued with their original practices; (3) that explores the mathematics of different groups in everyday settings showing that mathematical knowledge is generated in a wide variety of contexts by both adults and children -- focusing on the connections between cognition, culture and context; (4) that focuses on the relationship between ethnomathematics and mathematics education -- i.e., focuses on the connections between mathematics found in everyday contexts and that in the formal school system. (Vithal and Skovsmose, 1997, pp. 134-135)

As teacher educator, I agree more with the fourth strand -- not forgetting the first strand -- then, the fourth strand "is the unifying strand as it pulls together the other strands". (Vithal and Skovsmose, 1997, p. 135)

Knijnik assumes with the concept of ethnomathematical approach that mathematics is cultural knowledge and that "its birth and development are linked to human needs" and places the ethnomathematical approach -- agreeing or coinciding partly with Gerdes (1996), from an epistemological viewpoint -- in the confluence of mathematics and cultural anthropology. Knijnik goes further introducing "into this confluence *pedagogical* and *sociological* knowledge as well". (Knijnik, 1997, p. 406 -- italic by the researcher.). Remember -- quoted before in this chapter -- that Gerdes, (1996, p. 909), writes that ethnomathematics is a relatively new field of interest... "that lies at the confluence of mathematics and cultural anthropology".

Knijnik attracts attention, however, to the fact that "it is important to reaffirm that merely glorifying popular knowledge does not contribute to the process of social change". (Knijnik, 1997, p. 409) Gerdes is very cautious when he compares the three levels on which one interprets ethnomathematics, namely (1) ethnomathematics and mathematics, (2) ethnomathematics and ethnology and (3) ethnomathematics and didactics of mathematics, writing that "maybe it is better to speak provisionally about an ethnomathematical accent in research and in mathematics education, or of an ethnomathematical movement" (Gerdes, 1995a, pp. 16-18), as expanded in section 3.1.

3.5 Ethnomathematics related to this study

In the foreword to Powell and Frankenstein (1997), D'Ambrosio presents some of his ideas about ethnomathematics. "I see ethnomathematics as a way of going back to basics. Of course, basics in the broad sense ... with the global objectives that constitute our common dream." (p. xvi) He continues that "naturally, everyone learns in school the fundamentals of mathematics - the basics! - that have, in such a cold and austerely precise way, produced bombs and destructive technology. Ethnomathematics may help us in our quest for affection and love in this sculpture". (p. xvii) He also mentions that a broader view of history -- understanding the role of mathematics and mathematics education -- contributed to his views of "ethnomathematics as a program in the history, epistemology, and pedagogy, in particular, of mathematics". (p. xix)

The next quotation is more related to this study, constitutes an invitation to teacher educators do work in the field of ethnomathematics, and includes one of the definitions of ethnomathematics by D'Ambrosio:

> As a research program, ethnomathematics invites us to look into how knowledge was built throughout history in different cultural environments. It is a comparative study of the techniques, modes, arts, and styles of explaining, understanding, learning about, and coping with the reality in different natural and cultural environments. (p. xx).

In this study the researcher chose as (socio-)cultural activity the traditional house building.

Based on the analysis of geometry in school mathematics text books as was done in chapter 2, there is sufficient evidence that there are mathematical activities related to traditional house building.

In this study it will be indicated which are some of those mathematical activities and how such mathematical activities and ideas can be incorporated in teacher education in Mozambique.

Ismael, in his study -- already referred to in chapter 2 -- entitled *An Ethnomathematical Study of Tchadji — About a Mancala Type Boardgame Played in Mozambique and Possibilities for its Use in Mathematics Education* first used this game and the three stones variant of Muravarava game in mathematics classroom and saw "... positive effects on attitude towards the learning of, and performance in probability. These outcomes were corroborated by qualitative research". (Ismael, 2002, p. iii)

Secondly he conducted an ethnographic research amongst master Tchadji players and finally he did an intervention with pre- and in service student teachers.

> The results of this phase indicated that the 24 teachers, who participated in the research, showed enthusiasm, satisfaction and excitement in experiencing the mathematical richness of Tchadji and in appreciating possibilities for the use of Tchadji in the mathematics classroom. They were able to analyse the game independently and to identify embedded mathematical ideas in the game, like logical thinking, counting and empirical and mental calculation. (Ismael, 2002, p. iii).

Ismael concluded that

> ... using such games in the mathematics classroom is suitable for improving students' performance in mathematics, because the students make practice more effective and become active in the learning process. (Ismael, 2002, p. 261).

By researching ways to incorporate plain and twill weaving (a practical cultural activity) -- also referred to in chapter 2 -- Cherinda (2002) devised an educational tool which he calls "weaving board" that one can use for learning and teaching sequences and series, patterns and combinatorics.

In conclusion one may remember that almost all ethnomathematics studies done by Paulus Gerdes include suggestions of the use of their results in mathematics education.

3.6 Mathematical Ideas

Ascher broaches the concept of culture -- present in the different definitions of ethnomathematics -- saying that it is subtle and multifaceted and that "what is significant for us, is that in any culture the people share a language; a place; traditions; and ways of organizing, interpreting, conceptualizing, and giving meaning to their physical and social words." (Ascher, 1991, p. 2). As example she says that the same or similar idea will be differently expressed and will have different contexts in different cultures. (p. 2)

This study is full of the concept of mathematical ideas. The researcher's view related to this concept is in agreement with that of Ascher, when this author writes that

> among *mathematical ideas*, we include those involving number, logic, spatial configuration, and, even more significant, the combination or organization of these into systems or structures, (Ascher, 1991, p. 2 -- italic by the researcher.)

and explains that mathematical ideas, as a whole, are rich and multifaceted and that there is no particular single path along which they must develop, or any single linear scale along which they could be ordered, in every culture. (Ascher, 1991, p. 2) Agreeing with Shirley, Ascher writes that ethnomathematics has the "goal of broadening the history of mathematics to one that has a multicultural, global perspective" that "involves the study and presentation of *mathematical ideas* of traditional peoples". (Ascher, 1991, p. 188 -- italic by the researcher)

The next chapter will present relevant works on African traditional house building and on use of cultural activities in mathematics education.

4. Literature Review

In this chapter the researcher shall relate what other authors wrote about African architecture or simply about African traditional house building, what is available and known about traditional house building in Sofala Province and examples of the use of cultural activities for example, mathematics related to traditional house building -- in mathematics education.

4.1 On African traditional house building

It was very difficult to bring together literature for this chapter because there are a few books about the architecture from southern Africa, and even less about Mozambique. In addition it was even more difficult to bring together the desired books for this chapter because this researcher is more interested in addressing the geometrical aspects of the traditional house building and there are a few authors who tackle the African architecture from a geometrical or mathematical point of view.

For example, Larson and Larson (1984) broach "*TRADITIONAL TSWANA HOUSING: A study in four villages in eastern Botswana*" from an architectural point of view ,with the objective of suggesting better and at the same time low cost traditionally built housing, with regards to climate and existing building materials in Tswana Villages. They discovered that the traditional housing in Botswana was not documented.

Two of the motivations for Larson's study were that "The types of indigenous housing common around Independence could possibly shortly cease to exist.", (Larson and Larson, 1984, p. 10) and "... the belief that Tswana housing is of value and has merits that should not only be recognized but also taken advantage of in the development of housing in Botswana" (ibid, p. 10).

Apart from the study of the mathematics involved in the traditional house building, one bears also in mind, in Mozambique, the valuation, preservation and the enrichment of one's culture in terms of traditional house building, among other cultural aspects. Larson and Larson (1984) relate in their work to the composition of the dwelling and the use of the space.

In this study the houses are viewed as loose units and not as a whole, not as a dwelling unity or settlement. Even though there are mathematical aspects related to Settlement Patterns, such as Fractals, they are not of interest for this study. -- For example, Eglash (1999) in his book *African Fractals* analyses the architecture through aerial views of African palaces, settlements and other types of house groups.

The researcher could not avoid some data confrontation or comparison already in this chapter, given that he accessed part of the literature only during the data collection both in Zambézia and in Sofala Provinces.

4.1.1 General studies on African traditional house building

In this section studies, done by other authors, on African traditional house building, which focus not only the oriental, tropical or southern Africa region, will be reviewed. The objective of this part of the work was to have and to show a general overview of the forms and techniques used in traditional house building in different African Regions, especially south of Sahara.

Herman Frobenius in his book of 1894, *"AFRIKANISCHE BAUTYPEN — Eine etnographisch-architektonische Studie"*, gives a general overview about the

evolution of house building in Africa and he was surprised at the fact that the African people today construct houses mostly with sticks/poles and mud, when centuries ago they used stone very well. Apparently he finds no justification for this lack or absence of continuity in the evolution of the African traditional house building. But, it is not overstated that one can find the justification in the colonialization. Colonialists tried to banish the native's culture and at the same time placed the native in a status of an intellectually inferior being.
Frobenius (1894) differentiates four traditional house types in Africa, namely:

1. **Semispherical wall-less or wall-free house**

   (Halbkugelförmigen Wandlosen Hütten or simply *Kugelhütten)*

   This house type is built by the Bantu. (Frobenius, 1894, pp. 11-13/29-38)

2. **Cylinder-Cone-shaped house**

   (Cylinder-Kegel-Hütten or *Cylinderhütten mit Kegeldach)*

   This house type is found among the Betshwana and the Marutse. (Frobenius, 1894, pp. 16-21).

   This type of house has, sometimes, concentric rooms, especially by the Marutse. (Frobenius, 1894, pp. 44-48)

3. **House with square base**

   (Hütten auf quadratischen Grundriss)

   This house type is built by the Bantu (Frobenius, 1894, pp 38-43).

4. **House with rectangular base**

   (Gebäude mit rechteckigem Grundriss)

4.1 By Massai and Tembe-Bantu people.

   According to Frobenius a house type with rectangular base reaches the central and eastern Africa through the Massai or Maasai, from north. And adds that an influence from the Arabs is also probable. (Frobenius, 1894, pp. 49-52)

4.2 House with saddleback roofs

(Sattledachartige - Hütten or Sattledach-häuser)

Houses with rectangular base, no walls, built by the Marutse (Frobenius, 1894, pp. 21-23) and with walls, built by the Bantu and the Bakongo (Frobenius, 1894, pp. 38-43).

Unfortunately, this author doesn't explain how the circle, the square and the rectangle are constructed, and when the Maasai reached eastern Africa. According to Frobenius (1894) the houses with square bases have their origin in the western part of Central Africa, whereas the houses with cylindrical walls, i.e., with circular base have their origin in the eastern part of the same region.

In her famous book *"AFRICA COUNTS: Number and Pattern in African Cultures"* (third edition, 1999) Claudia ZASLAVSKY dedicates a chapter to GEOMETRIC FORM IN ARCHITECTURE. Zaslavsky (1999) writes that "the African adapts his home admirably to his means of subsistence, to the available materials, and to the requirements of the climate", and further says that "Confronted by a scarcity of building materials ... the African chooses the circle as the most economical form. He is not unique; round houses are constructed in the Artic as well as at the Equator." (1999, pp. 155-156).

Further, comparing the areas of a circle, a square and a rectangle of a given perimeter she comes to the conclusion that

> For given perimeter of 44 feet, the area of the square is smaller than the area of the circle by 33 square feet, or 21%. With the rectangle we lose 49 square feet, or 32%, compared with the circle. Obviously the round house has the lowest requirements in terms of materials and expenditure of time and energy (Zaslavsky, 1999, p. 156).

She describes an interesting procedure on how to build a *beehive-shaped* traditional house used by the Chagga in Tanzania. From this procedure the researcher will detach the construction method for a circle. “To mark off the circumference, the builder tied a hoe to a rope of length equal to the desired radius, two to three *laa*. The rope was attached to a peg, and as he walked around this peg, he drew a circle with his hoe.” [*Laa* is the span from the finger tips of one hand to those of the other, by outstretched arms.] (Zaslavsky, 1999, p. 158).

Zaslavsky recognizes three house types:

1. beehive-shaped house;
2. cone-cylinder house;
3. square or oblong house.

Among the *square or oblong houses* she details the *rectangular round-topped houses* built by the nomadic cattle-herding Maasai of Kenya and northern Tanzania.

For Zaslavsky,

> the introduction of rectangularity in the architecture of the west African grasslands and the East Coast has been attributed to the influence of Islam. In 1495 Askia Muhamad the Great, most famous ruler of Songhai, employed guilds of masons to construct cities of oblong buildings — mosques, Koranic schools and ordinary dwellings. (Zaslavsky, 1999, p. 166)

and further writes that “on the other hand, not all Islamized folk gave up their traditional circular houses”. (Zaslavsky, 1999, p. 166).

DENYER (1978) wrote the work *“AFRICAN TRADITIONAL ARCHITECTURE: An Historical and Geographical Perspective”*. As the title indicates, this perspective might not have many connections with the researcher’s geometrical objectives. But this conclusion is not correct, and Denyer's work will be quoted in several parts of the present study.

Denyer's study covers *Quelimane* -- Chuabo or Cuabo (See Denyer, 1978; map 2, under no. 29, p. xi; map 5, p. xiv and p. 149, figs. 229-230) -- and *Sofala* (See Denyer, 1978, p. 36), areas of the present research and shows a round house from Cuabo - Mozambique (from about 1900). But the researcher thinks that there is a mistake, because round houses are not typical for that Mozambican region or suitable for temperatures of over 50°C referred to by Denyer (1978, p. 149). As a matter of fact Denyer writes *"**Cuabo(?) house**, near Chametengo, Mozambique, about 1900"*. (Denyer, 1978, p. 149 -- **Bold** by Soares). The *question mark* by Denyer could be a clear indication of a doubt about the origin of the house type. The problem with names of the ethnic groups is recognized by Zaslavsky when she writes that

> a related problem is that of names of ethnic groups, variations in the names, and variations in their spellings. A people may call themselves by a certain name but may have different appellations in the languages of their neighbours, the Arabs and Europeans of various nationalities. (Zaslavsky, 1999, p. xiv).

So, it is possible that the Cuabo or Chuabo referred to by Denyer are not the people referred to by the researcher of this study.

As discussed later in sections 6.4.1 and 7.2 of the present study, the Chuabo, Chuwabu or Cuabo (people who speaks Echuwabu or Echuabo) house builders from Southern Zambezia hardly ever construct houses with no rectangular/squared base. Denyer points to four types of houses among the hunters, gatherers and some pastoralists; homes which could be dismantled and transported (Denyer, 1978, p. 95). Altogether, in the chapter entitled *A Taxonomy of House Forms*, Denyer points to 32 types of house style and for her, house "style is defined here as not only the form of individual buildings but also the way they are arranged" (Denyer, 1978, pp. 132-157). Denyer (1978) further notes that the shape of the roof was usually strictly related to the shape of the walls. Roofs above round walls would be conical, and roofs above rectangular walls would be saddleback, hipped or pyramidal. The Bamileke houses provide a particularly interesting exception because they have conical roofs resting on square walls. (1978, pp. 95-96). By *square walls* one may understand walls of a house with *square base* -- researchers understanding. Denyer's work is very interesting and very detailed and thorough. It can be very useful, especially for this researchers study on traditional house building as said above in this Chapter 4, given that in this work Denyer relates different points of view, such as of natural sciences with social sciences.

"AFRICAN ARCHITECTURE: Evolution and Transformation", by Nnamdi ELLEH (1997) is another work consulted for this research. Elleh (1997) elaborates on the architecture of each region and country in Africa. Elleh "…tries to provide a comprehensive account of the evolution, transformation and development of African architecture (Elleh, 1997, p. xiii). However, this review will concentrate on the architecture of the Eastern and Southern regions of Africa, particularly on Mozambican architecture. For Elleh (1997), and the researcher agree on the notion that traditional house building in Africa is determined to a great extent by the distribution of natural building materials and climate.

Elleh (1997, p. 4) criticizes the existing "... presumptuous belief that Africans do not have the ability to build any magnificent structure and that any architectural monument in Africa is of Euro-Asian origin".

Elleh (1997, pp. 8-14) explains Professor Ali Mazrui's concept of *The African Triple Heritage* and relates it to African architecture. Thus, the contemporary African architecture can be seen as a result of

(1) indigenous;

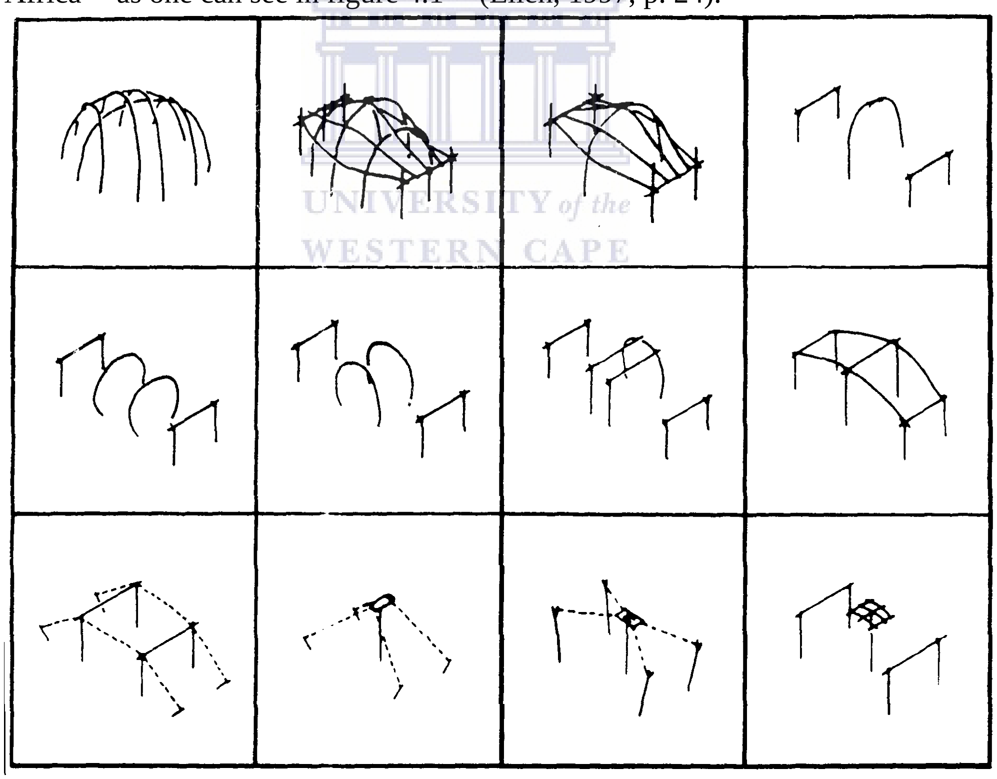
(2) Islamic (Semitic) and

(3) Western (Greco-Roman) legacies -- the modern culmination of a much older triple heritage. And concludes by writing that

> the fundamental issue here is that the triple heritage of Africa is a cultural reality that influences the lives of Africans and forms a strong foundation for studying the history of African architecture. (Elleh, 1997, p 14)

and "... to show that traditional African architecture is the first segment of African architecture". (Elleh, 1997, p. 19).

Elleh presents tent structures, with circular and rectangular base, used in Africa -- as one can see in figure 4.1 -- (Elleh, 1997, p. 24).



Tent structures used in Africa (Elleh, 1997, p. 24, *from Labelle Prussin*)
Fig. 4.1

About Mozambique Elleh writes, for example that "the aborigines of

Mozambique come from various major language groups, such as the Bantu and Khoisani peoples. Today, the Cuabo, the Nyasa, the Tonga, and some Shona live in Mozambique" (Elleh, 1997, p. 191) and further on concludes that "the Shona civilization, a Bantu-speaking group that migrated from the north before the 10^{th} century" (p. 209) and that "the Shona civilization extended from the interior area of the Kalahari Desert to the East coast of Africa in present-day Mozambique" (Elleh, 1997, p. 209).

In the book *"GEOMETRY FROM AFRICA: Mathematical and Educational Explorations"*, from 1999, Paulus Gerdes writes, among many aspects related to geometrical ideas from Africa south of the Sahara, about two methods of rectangle construction used in traditional house building among the Mozambican peasantry and explores them geometrically.

Still on traditional house building Gerdes (1999, p. 94) writes that "most African people south of the Sahara traditionally build houses with circular or rectangular bases".

These two rectangle construction methods -- one of them also found by the researcher in Zambezia Province -- are presented in Chapter 6 as *6.1.2a) The first method* and *6.1.2h) The eighth method.* They will not be presented in the current chapter in order to avoid data repetitions.

Furthermore, Gerdes (1999, pp. 96-97) presents generalizations and variations of the two construction methods for the rectangle.

4.1.2 Studies on traditional house building of tropical and oriental Africa

In this section studies done by other authors about house building in the African region where Mozambique lies will be related. It includes the oriental, tropical and southern Africa. In this section a closer idea will be explored about the techniques and house forms used in countries near Mozambique, so that one is able to understand and interpret better the work done by Mozambican house builders, particularly from Zambézia and Sofala.

As said before, Larson and Larson broach traditional Tswana building in eastern Botswana, an African tropical country. Larson and Larson (1984, pp. 98-100) classify the traditional houses as *circular* and *rectangular* houses. According to these authors, turning to early records, the circular house, often called the *rondavel*, is the oldest indigenous shape of traditional Tswana housing in Botswana.

> To mark out the location of the wall, nails and string are often used. For circular houses the nail is put in the centre of the house-to-be and the string is used as compass. In a similar way, the walls of a rectangular house are marked out with string between nails in the four corners. However, right angles are not constructed for the corners. Sometimes the line is just marked out with the foot without string (Larson and Larson, 1984, p. 111).

Therefore, among the Tswana house building of Botswana a builder would have one method to construct the circle and two methods to construct the rectangle.

Moriarty (1980) relates the case of *Traditional Housing in Tanzania*, a tropical country like Mozambique. He indicated that around 1980 over 90% of the approximately 16 million people in Tanzania lived in rural areas (1980, p. 285). For Moriarty,

> Tanzania — and indeed tropical Africa in general — is fortunate from a housing viewpoint in having such a large percentage of its population rural, as housing needs are more easily satisfied there than is possible in the urban centres. In rural areas, the materials for traditional housing types are still

> widely available, as are also the skills needed to fashion them into a dwelling (Moriarty, 1980, p. 285).

Unfortunately, the same cannot be said about the case of Mozambique, at the moment. The 16 years of civil war, which ended in 1992, caused a population exodus from rural areas to the towns where many people live with housing problems and in the rural areas it is not always easy to get good building materials, and people are afraid of land mines.

According to Moriarty (1980) the Tanzanians came in the 19th century "... into contact with western housing styles and materials; some as labourers building houses, others as servants clearing or guarding them or merely as residents of — or visitors to — the towns". (Moriarty, 1980, p. 285) points to a very interesting and important consideration when he writes that "... to justify their 'civilizing mission' — a colonial (or trusteeship) authority can hardly afford to find much of value in local technology", (Moriarty, 1980, p. 285) and so the European housing styles in Tanzania, and elsewhere, were very different from local ones. There are naturally other reasons for this difference. According to Moriarty (1980) even before the coming of the Europeans the most commonly used building materials were still the locally-available ones, like mud, ground, poles, thatch and stone, without foundations. For him in Tanzania

> the impact of European housing technology has changed African housing designs, or at least, housing aspirations, in two major ways: first in the choice of building materials and, secondly, in the physical form of the dwelling (Moriarty, 1980, p. 286).

For example, the shape of dwellings has changed with time. The traditional hemispherically-shaped house of grass and sticks is replaced with rectangular constructions (rectilinear construction) because this last shape is adapted to metal sheet roofing, the first housing innovation in rural areas in Tanzania. (Moriarty, 1980, pp. 286-288)

Other work related to African traditional house building is *"AFRICAN TRADITIONAL ARCHITECTURE: A Study of the Housing and Settlement Patterns of Rural Kenya"*, by Kaj Blegvad ANDERSEN (1977). In Andersen's book, in general, there are answers to two basic questions:

(i) *Why* does someone build and **(ii)** *How* does he/she build?

For the researcher, who is not an architect, the questions are:

(1) ***How*** *does someone build* and, afterwards

(2) ***Why*** *does he/she build like that?*

So, the interest is in mathematical aspects and not in sociological, geographical, anthropological aspects. However, these aspects can emerge in the answers to the second question. "The study of how man builds does not present problems. It is only when trying to relate the **how** and the **why** that difficulties arise" (Andersen, 1977, p. 7). The researcher agrees with this viewpoint because only by relating the **how** and the **why** is it possible to come to the thinking of the house builder, to his knowledge and, especially, to the imagination of the inventor of the building method (cf. Gerdes, 1995a) whereas the study of *how someone builds*, from the researcher's view point, can be only a question of *describing* procedures. According to Andersen,

> the traditionally built house in Kenya is definitely not mere shelter. It is, together with the tools and the equipment found inside, the home, an expression of the people's culture and a national asset. (Andersen, 1977, p. 24).

The Government of Mozambique had the same understanding about the traditionally built houses and traditional dwellings. So research done in the early 1980s, ca. 5 years after Independence, on behalf of the former Ministry of Education and Culture, National Service for Museums and Antiques, under the designation of Cultural Preservation and Valuation Campaign, included a survey of traditional housing in Mozambique. Unfortunately, that survey had no continuity, at least in Sofala Province, and most of the surveyors were *primary school teachers and students* not very well prepared for that kind of research.

Andersen showed that even as late as 1977 a variety of traditional houses were still found in rural Kenya as well as the material used for their building. He described circular houses with conical roofs and rectangular houses, with walls made of poles and mud. About the rectangular houses in Kenya he writes that "... for instance the rectangular house which, though still utilizing the poles, mud and daub of traditional past, was openly borrowing from European models in its structure" (Andersen, 1977, p. 28) and justifies saying that "the use of such sheeting (corrugated iron sheets) has altered the shape of the traditional house from circular to the rectangular, ...". (1977, p. 34).

The case of Mozambique, at least as shown by the house builders from Zambézia Province, is different, as will be justified in Chapter 8. However, Andersen is correct when he writes that

> the influence of other cultures in the building of African indigenous houses has certainly not always been for the good. This is mainly because change has been introduced so rapidly that essential qualities in traditional architecture have been lost in the technical execution of the houses. (Andersen, 1977, p. 33).

For example, iron sheets provide very poor insulation against the heat of the sun by day (in tropical Africa) and the loss of heat during the night. Andersen

(1977, p. 35) divides the traditional houses with circular base into three types or categories, looking to the materials used:

1- Composed of rigid elements;

2- with flexible elements which are planted into the ground at one end;

3- with flexible elements which are planted into the ground at both ends.

Andersen indicates two thatching methods:

(**i**) the flush method and

(**ii**) the layered method. (Andersen, 1977, p. 156).

He describes briefly the circle construction:

"The round shape of the huts has been adopted for practical reasons. A circle is the easiest way of setting out a house and needs only a string of a certain length and something to peg it down", (Andersen, 1977, p. 38) or "the building area is marked by drawing the perimeter using a piece of string attached to a peg in the ground," ... (Andersen, 1977, p. 132). Andersen (1977) refers to houses which are rectangular in shape but rounded off at the corners, but unfortunately he doesn't explain how one draws this kind of rectangle. Andersen's work is very rich in anthropological aspects.

The Literature Review presented here had as objective a scan of the knowledge about the African traditional house building, its relation with the traditional house building in Mozambique as well as the knowledge of the main components to observe and that at the same time determine or characterize an African traditional house. Therefore, it had to deal with some literature selected *independently* from the Theoretical Framework of this research -- The Ethnomathematics.

4.2 Earlier studies on traditional house building in Sofala

Related to earlier work on traditional house building in Sofala Province, the researcher studied 21 inquiries done in the early 1980s on behalf of the Ministry of Education and Culture, former National Service for Museums and Antiques, with the designation *Cultural Preservation and Valuation Campaign*, kindly loaned by ARPAC-SOFALA (Cultural Heritage Archive -- in Portuguese). These inquiries describe traditional dwellings and traditional villages in Sofala Province. In these inquiries one also found the names of the base shapes of the houses, roof types and building materials in *Cisena* and *Cindau*, the two most spoken bantu languages in Sofala Province. The researcher also found out that the house walls were decorated with geometrical figures and animals, using mud of different colours. Unfortunately, it was not possible to have similar data from Zambézia Province, because there is no ARPAC in this Province.

4.3 On the use of cultural activities in mathematics education

Mozambique became independent from Portugal in 1975. Thus, after more than 30 years of independence, Mozambicans cannot allow that mathematics still remains an elitist discipline. Criticising this state of affairs Gerdes wrote: “Mathematics education is therefore structured in the interests of a social elite. To the majority of children, mathematics looks rather useless.” (Gerdes, 1986, p. 19).

The Mozambican National System of Education, introduced gradually from 1983, was accompanied with new text books in the different subjects. Related to mathematics Gerdes wrote:

> In the new books, one starts by posing one or more (mathematically) related practical problems; then one proceeds to do a theoretical elaboration and develop the corresponding mathematical skills and at the end of each theme there are presented many different practical problems where the learned mathematics techniques can be applied. (This second “formal” phase is still underestimated by many teachers, who think it is only necessary to operate with concrete objects.). These practical problems are not artificial nor borrowed/copied from “European” curricula; ... (Gerdes, 1986, p. 24).

Almost all ethnomathematics studies done by Gerdes -- and work from the Mozambican Ethnomathematics Project in general -- include suggestions for the use of their results in mathematics education. For example, Gerdes (1999, pp. 96-97 and 1991, pp. 64-67) describes two construction methods for the rectangle used by Mozambican house builders, looks for “... interesting didactic alternatives of axiomatic constructions for Euclidian geometry in secondary education or in teachers’ education”, and then presents generalizations and variations of the two rectangle construction methods, that one can deal with in geometry classes.

In Gerdes’s (Editor,1990b) mathematics text book for the grade 8 one uses figures of square mats woven with vertical and horizontal strips in exercises about rectangular Cartesian coordinate systems (p. 55). One also uses circular basket bowls (pp. 59-60) for the introduction of, and for exercises on the concepts of circumference, diameter, radius, centre, chord, etc . The example of circular basket bowls is also presented in Gerdes (1999, pp. 106-110) and includes a study of an approximation of the area of a circle and the properties of the circle using circular rings and square mats.

In the same book Gerdes (1999, pp. 54-78) shows

> ... how diverse African ornaments and artifacts, varying from woven knots, to symmetrical designs, and to infinity decorative patterns, may be used as a starting point to create an attractive educational context in which students may be led to discover the Pythagorean Theorem and find proofs of it. (Gerdes, 1999, p. xiii).

Lumpkin and Strong (1995), in their work titled *Multicultural Science and Math Connections* suggest *middle school projects and activities* inspired in cultural activities including house building, circle and rectangle construction methods and the use of model houses. Adam, who reports on mathematical ideas related to counting in Maldivian society, more specifically related to traditional and cultural context -- using contextual examples of counting in fishing, agriculture and money. He states that

> this study seeks to explore the nature of indigenous mathematics thinking in Maldives, so that future curricula can consider the inclusion of these indigenous ideas and practices. (Adam, 2002, p. 1)

Borba writes that,

> if different people produce different kinds of mathematics, then it is possible to think that about education as being a uniform process to be developed in the same way for different groups. Instead, *mathematics education* should be thought of as a *process in which the starting point would be the ethnomathematics* of a given group and the goal would be for the student to develop a multicultural approach to mathematics. (Borba, 1997, pp. 266-267 -- *italic by the researcher).*

And Fasheh adds on by saying that

> teaching maths through cultural relevance and personal experiences helps the learners know more about reality, culture, society, and themselves. That will, in turn, help them become more aware, more critical, more appreciative, and more self-confident. (Fasheh, 1997, p. 288)

Staats (2006) presents a 'socially contextualized' approach for integrating ethnomathematics into undergraduate classes. In this approach, students engage issues associated with an application or case study, that are significant socially and anthropologically in tandem with the mathematics lesson (Staats, 2006, p. 39).

Staats concluded that engaging social issues associated with well-known ethnomathematics case studies, such as Tschokwe *lusona* and Vanuatuan *nitu* sand drawings allow students to develop subjective, values-based motivation to the study of mathematics. (Staats, 2006, p. 39).

Harding-DeKam (2007) in his article titled *Foundations in ethnomathematics for prospective elementary teachers* relate a Mathematics Methods Course during which Prospective Elementary Teachers were instructed on how to teach children learning second languages and children of diverse cultures.

The researcher found this experience of interest because the majority of Mozambican children have the first contact with the school in a second language. They study the subjects in the school syllabus at the same time that they learn the language of schooling – Portuguese (Mozambique has more than 30 national Bantu languages and dialects).

As conclusion Adam writes that

Ethnomathematics has important implication for curricula. The mathematical ideas related to counting can be used in curricula so that students can make connections between formalized ways of counting and their everyday life. Furthermore, this would enable students to make sense of formal mathematics. (Adam, 2002, p. 8).

Whereas Gerdes writes that

we may conclude that the incorporation of mathematical traditions into the curriculum will contribute not only to the elimination of individual and social psychological blockade, but also of the related cultural blockade. (Gerdes, 1986, p. 26).

The meaning of *psychological blockade* was explained in Chapter 3.

Let us complete this chapter by quoting the late Mellin-Olsen. He doesn't give a definition, but considered culture as key theme for Mathematics Education and wrote:

— culture is related to the activities of living people - and so is education;

— culture is in some way related to knowledge - and so is education. (Mellin-Olsen, 1986, p. 99).

And further wrote that "whatever culture can be, we have to bear in mind that culture is produced" (Mellin-Olsen, 1986, p. 100).

That is: knowledge, language and values are not only taken over from former members, they are also used and applied in new situations, developed and transformed, and used again, that is, not only reproduced, also produced. (Mellin-Olsen, 1986, p. 101).

The next chapter will deal with methods and techniques used for data collection.

5. Research Methodology

In this chapter the researcher presents the methodology used for collecting the data. Details will be presented on methodology used for collecting data related to the first research question -- *What mathematics is involved in the traditional house building?* The method used for data analysis will be presented in chapter 8. In order to suggest *how the knowledge involved in traditional house building can be incorporated in Mathematics Education* text books will be analysed in confrontation with the results of chapter 8, and tasks will be formulated for chapter 9.

5.1 Methodology for data collection

The data collection will be based on different methods and techniques.

The researcher tried to register on video a process of house building, but due to the lack of electricity in the rural areas it was not possible to use this method. The objective of this method was that, with a registration on video of a more or less an entire process of constructing a traditional house, it could be posible to view the process of traditional house construction repeatedly and, perhaps, enrich on the understanding of the process. He had the idea that one can understand better what the house builder says when one is able to see at the same time what he is doing. But, this deficiency was overcome through the use of other techniques for data collection.

First the researcher presents the list of techniques or means and then he presents how each technique or mean was used and what kind of data was collected with this technique. All these techniques were used under the qualitative research methods of *Participant Observation* and *unstructured* *interviewing.*

• Interviews;

• Recording with photos;

• Recording on audio cassette and Field notes;

• Recording with line drawings;

• Unsystematic or unstructured observations;

• Measuring;

• Unstructured conversations and

• Survey on existing data (or document analysis).

• General literature review.

According to Burns, research is “a systematic investigation to find answers to a problem” (Burns, 1994, p. 2).

Between the quantitative and qualitative modes of research, the qualitative method, that emphasises the importance of subjective experience of individuals, seemed to be the most adequate for the nature of this study. To that Burns states that “only qualitative methods such as *participant observation* and *unstructured interviewing* permit access to individual meaning in the context of ongoing daily life” (Burns, 1994, p. 238 -- *italic by the researcher*).

In agreement with Burns (1994), the researcher is convinced that the nature of data that he intended to collect from the house builders could not be collected using a previously prepared inquiry. Maybe that could be possible if the researcher, himself, became a house builder. For example, some of the questions to the house builders arose just during the conversations, so that it was not easy to prepare all the questions in advance. Other sides, for example, the researcher was not interested in finding out how often one uses a given method of rectangle construction, but he was interested in which methods do exist, their description, the justification of their use by the house builders, etc. Such kind of data is difficult to collect using *quantitative methods*.

Further Burns writes that “social reality is the product of meaningful social interaction as perceived from the perspectives of those involved and not from the perspective of the observer” (Burns, 1994, p. 238). By the method of participant observation the researcher “lives as much as possible with and in the same manner as the individuals being investigated. Researchers take part in the daily activities of people, ...” (Burns, 1994, p. 259).

So, a research of this kind has to be done in a long period of time, not in a short time using only a previously prepared set of questions.

The data collection was done by the researcher and by his students (as research assistants) in the provinces of Zambézia and Sofala. He had more time to stay with the house builders, especially with three of them, in Zambézia Province, for unsystematic observations and unstructured interviews, than his students, who visited the house builders once or twice in preparation of a guided interview, in Sofala Province. The researcher was able to visit more districts in Sofala Province (10, included the rural area of the town of Beira, where the people speaks *Cisena*) than in Zambézia Province (3 of 7, where the people speak *Echuwabu*). Because (i) the researcher is living and working in Sofala Province and (ii) in the years 2001 and 2002 he was integrated in a multisectorial or multidisciplinary team, which, divided in groups, visited the province in preparation of a 10-years Development Plan for the Sofala Province. Altogether, Sofala has 13 and Zambézia 17 districts.

5.1.1 Interviews, Recording on audio cassette and Field notes

Burns (1994) emphasizes that “within educational research the typical qualitative approaches involve ethnography survey and action research, with observation and interviewing as the major techniques”. (1994, p. 241). Further he explains that “many fieldworkers complement data from participant observation with information taken from interviews” (Burns, 1994, p. 264).

The interviews done personally by the researcher in Zambézia Province were recorded on audio cassette. Afterwards they were transcribed into Portuguese. The interviews made by the student assistants, given that they were working in groups, were directly written on paper in Portuguese by one of the group members, with some words in Echuwabu or Cisena, while another member was asking the questions -- most of them from the auxiliary guide.

With the registration on audio cassette of the interviews and conversations with the traditional house builder he was able, in case of doubt, to re-listen to the interviews, if necessary. Experienced interviewers know, and some authors recommend that recorded interviews be used together with some field notes, just incase the recording technique fails. So the researcher took some notes even if the interviews were recorded on audio cassette.

With some questions in the interview guide, the researcher was trying to find out if the house builder was aware of certain mathematical knowledge which he/she used while working. For example, the question 6 -- *How are you going to straighten the base if you notice that a distance measured by a line, for example AC, is longer than the other, BD?* -- was made in order to find out if the house builder followed some logical thinking by straighten the base, so that he/she could quickly reach the solution, the rectangular base. The question 12 -- *How do you differentiate, in your mother tongue, a base with all sides equal from a base with each two opposite sides equal but not all four sides equal?* -- had a purpose to “capture” in the builders mother tongue the words for *rectangle* and for *square*.

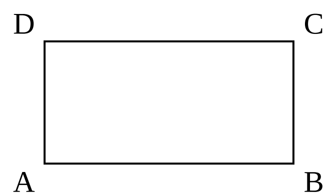
Here we have the interview Guide that the researcher considers to be a semi-structured one. There are only some of the necessary questions for the research. Many other questions emerged during the data collection, during the conversations and observations, while the researcher slowly familiarized with the process of traditional house building.

INTERVIEW GUIDE

Ten in English transcribed interviews can be found in an appendix.

(The questions 5, 6, 7, 12 and 15 are only valid for houses of rectangular base)

1. What is your name? *(If possible:* How old are you?*)*
2. Who built the house where you live?
3. How did you learn to build houses?
4. *(Keeping in a bag various sticks with at least four having the same length, in two different sizes and a line)* How do you arrange or prepare the base of a house?
5. *(If necessary)* How do you ensure that the base is exactly like you intended to do?
6. *(In case of using a line to measure the diagonals)* How are you going to straighten the base if you notice that a distance measured by a line, for example AC, is longer than the other, BD?



7. How do you know that this method brings in “perfect” shape for the base?
8. Do you know any other method to prepare the base of a house?
   (Let him/her describe the method, ask him/her why does he/she not use it)
9. *(In case the builder once joined school)* Did you go to school, have you learnt these method(s) at school?
10. From where the person who taught you learn this method, and building houses in general?

11. After doing the base, it's sure that the following step is to place pillars. How do you ensure that a pillar is well placed?
12. How do you differentiate, in your mother tongue, a base with all four sides equal from a base with each two opposite sides equal, but not all four sides equal?
13. What inclination have you used for the roof?
14. To what extent does the roof inclination influence the fact that a house drops or not?
15. Which orientation do the houses you build follow? Which orientation do the houses in general follow?
16. If you were living close to a mountain or near to the beach, which orientation could the houses follow?
17. How did you learn to build a house?
18. How did you know that you could build a house, yourself (personally)?
19. What kind of tools do you use? Are there any other tools that you miss for your job?

20. How could you teach anybody to build a house and how long could he/she take to learn?
21. In building walls, some builders use lines or rope to tie up the sticks and others use nails. Which material do you use, nails or lines, and why?
22. In which stages do you divide the (process of) building a house?
23. What is the most difficult stage?
24. If the house builder is describing a building process of a house with circular base, additional questions must be asked:

24.1 How do you mark the positions for the posts?

24.2 When the roof is made outside the wall frame, how do you determine the size of the roof?

24.3 When the house has two walls, how do you determine where each wall passes (the two circular bases)?

24.4 When you are placing the beam, how you know that the (house) wall both at the top and at the bottom will have the same size?

25. (The interviewer must try to obtain, in a builder's language, words or expressions that refer to:)

 1. angle
 2. vertical
 3. horizontal
 4. oblique
 5. ranged
 6. middle
 7. center
 8. apex or corner
 9. straight
 10. curved
 11. diagonal
 12. rotation
 13. translation, etc.

In some Mozambican cultures it is not polite to ask for the age of a person older then oneself -- so therefore the question: *If possible:* How old are you?

The students who helped the researcher with the collection of data in the Sofala Province were fluent in the mother tongues of the house builders. In addition to that they were students who had concluded 3 years of a 5-years university level course in Mathematics Education -- *Licenciatura* -- (and have written a bachelor's thesis), had 160 hours of *History of Mathematics* and at least 48 hours *Ethnomathematics* classes. So, in the researcher's view, they were sufficiently prepared to do this kind of interviews.

The researcher agrees that given the nature of the problem -- *What mathematics is involved in the traditional house building?* -- it could have been better if he, or his students, participated directly in the building of traditional houses as an apprentice, as a helper, etc., as suggested by many authors. But, given the limited time, this situation was overcome by using students who were fluent in the mother tongues and cultures of the house builders, in order to, in a short space of time, ensure that they (the students) could win the house builder's trust. (He had more time to stay by the house builders in Zambézia Province as observer and interviewer.). However, he knows that it is not only a question of winning the house builder's trust, but, as Ascher (1991) writes,

> we are limited by our own mathematical and cultural frameworks. It is more likely that we can see or understand those ideas that are in some way similar to our own, while ideas that we do not in some way share may escape us. (Ascher, 1991, p. 3).

Or, as Borba (1997) argues that

> it is important to remark that dialogue cannot take place if the realms of concern of the human beings involved in the dialogue have no intersection. In other words, if the problems which involve them are completely different, the dialogue cannot occur (Borba, 1997, p. 263).

And, for the researcher, the data collection was and may be full of dialogue, and not only of questions and answers.

5.1.2 Recording with photos and with line drawings

Given that the results of the research will not only be directed to people who are familiar with Mozambican *traditional house building*, photos and line drawings can help one to understand the data presented in this study and can also serve as a source for the validation of the data. However, because of the trees around the houses and the lack of colour contrast among the building materials, and between the materials and the soil, especially near the coast, often all brown, line drawings are more used than photos.

The photos and the line drawings were made by the researcher or taken from other sources properly indicated in the title of the figures or pictures.

5.1.3 Unsystematic observations and conversations -- field notes

Sometimes the (working) house builders had not time for an entire interview. In these cases the researcher stood next to them and observed making few questions and taking some notes. Afterwards, he used his notes and reflections to formulate new questions for next conversation. As said in section 5.1.1, it was not easy to predict all questions in the guide. So, sometimes the house builders were not asked the same questions -- house builders' methods and answers could provoke new questions. See examples of questions that were not in the guide presented in section 5.1.1:

* In interview Zambézia-1
    - Some house builders prefer the use of a square to determine the base of the house but you prefer the use of rope. Is it because you don't have a square?
* In interview Zambézia-3
    - How long ago did you construct your first house?
    - That is according to roof type. But, what is the name according to the base? Some people call it *nyumba yelapi* (house of length = house of rectangle). Is that correct? When it is like this (pointing to a rectangle drawn on the

ground) they say that this house is of *elapi* (of elapi = rectangle, not squared), can one say that?

- Can it be the same person who first takes a position and afterwards the other position?
- Will there be someone on the top to maintain the upright stick *(muamba)* in the vertical position?
- How can you see from the bottom that with this *muamba* height the roof will have a good inclination and that it will not drop inside the house?

* In interview Zambézia-4
  - Why not she?
* In interview Sofala-1
  - Do you have something more to say, Mr. Domingos?
* In interview Sofala-2
  - When do you use sticks and when do you use rope?
  - Could you explain to us the procedure when you are using sticks?

Sometimes the unsystematic conversations served as a preparation for an interview, for the students, and for the creation of the necessary intimacy in the relationships between the house builder and the interviewers or participant-observers.

5.1.4 Measuring

This technique was used in order to compare the length and the width so that one could:

(1) calculate the ratio in rectangles, looking for eventual existence of golden ratio or other kind of ratio;

(2) calculate the ratio on rectangles in order to determine the roof type to be constructed;

(3) to calculate the angles of roof inclinations.

5.1.5 A survey on existing data (or document analyses)

Apart from the observations and interviews done with help of the shown interview guide, the researcher looked for earlier literature on traditional house building in Sofala Province. So, he worked with 21 inquiries done in the early 1980s on behalf of the Ministry of Education and Culture, former National Service for Museums and Antiques, with the designation *Cultural Preservation and Valuation Campaign*, kindly loaned by ARPAC-SOFALA (Cultural Heritage Archive).

The inquiry was divided in two parts (see translations in Appendix). The first part was an inquiry on traditional village and the second part was an inquiry on traditional dwelling.

The second part of the ARPAC's inquiry, related to traditional dwelling, was more useful for this study, in terms of adding some material to the data collection. For example, the denomination in Cisena of different house types and the materials used for traditional house building -- used by the house builders in Sofala -- were confronted and confirmed.

5.1.6 General literature review

The researcher went to do fieldwork as soon as he revisited the theoretical framework of the study -- the ethnomathematics, before he made a great advance in literature review. He studied with more indepth, the literature about *African traditional house building* after he collected some data from field. He inverted the "normal" order of the procedures because he wanted to avoid that the organizing of the data was influenced by conclusions drawn by non-African researchers which were not ethnomathematicians.

However, the researcher is convinced that it was proper to do that as his conviction is also supported by Burns who writes that

> literature review is a stimulus for your thinking and not a way of summarising in your own mind the previous work in the area that *can blind you* to only considering existing concepts and conceptual schemes as in quantitative method (Burns, 1994, p. 241 – *italic by the researcher*).

5.2 Validity and reliability of the study

The discussion of qualitative data includes not only the important issue of validity but also reliability, even if the issue of reliability -- *concerned with giving the same result consistently under the same conditions* -- is more requested and applied by quantitative data studies. But, given the fact that no one of the interviewed house builders, both in Sofala and Zambézia, asked for promise of anonymity, the issue of reliability can be seen differently in this study.

As said in the section 5.1.2, the photos and line drawings can serve as a source for the validation of the data. Additional sources for the validation of the data are the facts that all intervenients in the process of data collection (i) mastered the mother tongues and culture of the house builders -- the researcher, *Echuwabu (and scant Cisena)* , and the students, *Echuwabu* and/or *Cisena* -- and (ii) have sufficient experience in collecting data for scientific work. They mastered also the Portuguese language, the language of schooling in Mozambique. Some question could be translated from Portuguese into English.

The researcher started the collection of data in his native region, Quelimane, Zambézia Province, because, on one hand, he was sure that he could have more facilities to move around freely, since he knows the region and the mother-tongue or local language and, on the other hand, he could win some experience in order to face the data collection in Sofala Province using an unfamiliar language, *Cisena*, with the same “facility” and confidence. Even using students as interviewers this confidence was necessary, in order to accept easily their translations from Cisena into Portuguese.

In chapter 6 the researcher will describe the most important construction steps of a house of rectangular or squared base and, at the same time, will do some data analysis on this house type.

6. Data and data analysis on houses of rectangular/square base

This chapter consists of the description, on the basis of observation and/or statements or stories and interviews of the building or construction process of a house with a rectangular base (and a one-, two- or four-sided roof) by people with no (or little) schooling. The chapter also consists of the analyses of the underlying geometry and geometrical thinking/reasoning, as well as possible geometrical concepts used, preferably in local language (and their literal translation in English). It will also be important to describe the material used in detail, for a lot of mathematics, especially geometry can be hidden in the very production or shape of some materials. Because of the nature of the data to be presented in this chapter, some of them will be analysed as soon as they are presented, even if superficially. With this procedure the researcher tries to avoid too many repetitions of the data in chapter 8, which mainly focuses on general data analyses.

6.1 The building process of houses with rectangular/square base

In the next lines the researcher describes the most important construction stapes of houses with rectangular or square base.

6.1.1 Selection and preparation of the place to build the house

Often the construction process of a house begins with the selection and preparation of the ground. Only after the preparation of the ground can the builder have a clearer idea of the base size of the house to be built. Sometimes the owner of the future house gives the idea of the size of house to be built to the house builder by telling him how many divisions the house may have, how many people he/she has in the family (and the average of their ages) and which kind of furniture he/she has or is planning to have in this new house. In this case, the house builder has to indicate the more appropriate place to prepare the ground for the house. The preparation of the ground includes levelling (or flattening out) by the naked eye and one does not use a spirit or water level. It is not always that the ground can be completely levelled. Sometimes only after the house is ready one is worried about the levelling of or flattening out of the floor of the house and to put it on a higher level compared to the level of the ground.

In practice, sometimes, one first collects the materials to be used in the construction, and only then one prepares the ground.

The use of space is related to geometry. So the calculation of the size of the base of the future house, using the "size" of the family or the number of divisions, is therefore the use of geometrical ideas by the house builder, i.e., the house builder makes a geometrical abstraction. Not only that, but even in the conversation between the owner and the house builder, this exchange of ideas is geometrically covered.

Could the levelling of the ground be seen as a sign that the house builder may know that it is not easy to construct a perfect geometrical shape, circle or rectangle, on a non-level ground?

6.1.2 Rectangle constructions — eight methods for the construction of the rectangular base

During the data collection process, seven methods of rectangle construction were evident, i.e., seven methods to construct a rectangular base of a house. An eighth method was found only in the literature. From the first seven methods, one was also found in the literature by Gerdes (1991, pp. 64-67 and 1999, pp. 94-97) (This method will be classified as *the first method.*), and another two by Murimo (1997, pp. 1A-6A and 1B-8B) -- while he was a student. The order in which the seven methods are presented in the thesis is not important. To consider one method as the **first one** will not, for example, mean that it is the oldest one or the one most used by the house builders.

During the data collection, in the south region of the Zambézia Province, the researcher came across two different procedures to prepare the base of a house and one house builder told him about a third method.

6.1.2a) The first method

According to the first method, in order to construct a rectangular base the builder needs four long sticks. Each pair of sticks should be of the same length, depending on whether the base is squared (Fig. 6.1.a) or strictly rectangular (Fig. 6.1.b). The house builder starts by laying down the selected four sticks on the floor, so that they form the perimeter of a quadrilateral. With quadrilateral in this study the researcher will always be referring to *convex quadrilateral*. When the sticks are well adjusted he then takes a rope and with it he measures the diagonals and compares the lengths. The sticks are then further adjusted until the diagonals become equal. Only when the diagonals are equal can the builder be sure that the quadrilateral formed with the sticks on the floor is a proper rectangle, (Fig. 6.1.a and 6.1.b). This method is also described by Gerdes (1991, pp. 64-65 and 1999, pp. 94-97), as mentioned earlier.

It was confirmed that the method presented in Fig. 2.19, i.e., the use of two scaled ropes to compare the lengths of the diagonals in chapter 2, was influenced by techniques used when one works with paper and pencil.

This method reflects the knowledge that a quadrilateral with equal opposite sides and equally long diagonals is a rectangle. Or, looking only at figure 6.1a, one can say that *a quadrilateral with equal sides and equally long diagonals is a square*. The researcher agrees with Gerdes that when one uses this method the rectangular shape appears as the result of a continuous transformation of a quadrilateral, i.e., that a quadrilateral converges to a rectangle, the rectangle being the limit (cf. Gerdes, 1998).

Square base

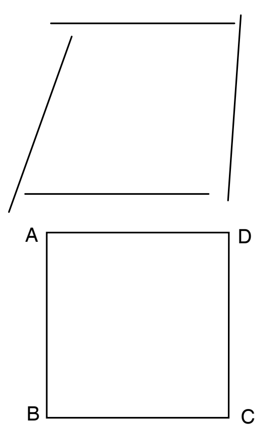


Fig. 6.1.a

Strictly rectangular base (or oblong)

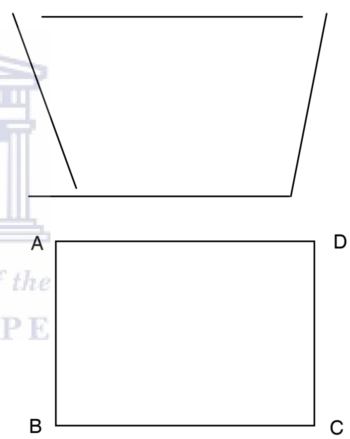


Fig. 6.1.b

6.1.2b) The second method

It was possible to find only one house builder who used this second method to construct a rectangular base for a house. This builder described only the construction of a squared base of a house, using his own house, built by himself, as example.

The house builder took a rope and measured on it one and half *armfuls*. (With *armful* is meant the distance from a fingertip of a hand to the opposite shoulder). Then he cut one and a half armfuls long stick, measured with the rope. After that he laid the stick on the floor and made a mark at each endpoint of the stick on the floor (Fig. 6.2.I) -- *the mark on the left is considered as the 1st mark.* Then, maintaining the stick fixed on the floor by one of the endpoints, he rotated it until a nearly right angle between the stick and its former position was formed on the floor and made a 3rd mark at the endpoint of the stick on the floor (Fig. 6.2.II). Next, he repeated the last step rotating the stick in the same direction of the former right angle, and made the 4th mark (Fig. 6.2.III). Finally, he laid the stick on the floor so that an endpoint coincided with the 4th mark and tried to reach the 1st mark with the other endpoint of the stick (Fig. 6.2.IV). If that is possible small sticks are pinned down on the marks on the ground which will be the vertices of the square base of the house (Fig. 6.2.V).

In case the other endpoint of the stick does not reach or exceed the 1st mark made on the floor, some adjustments will be made.

In order to complete the base of the house, the four small sticks on the ground are rolled up with a rope (Fig. 6.2.VI)

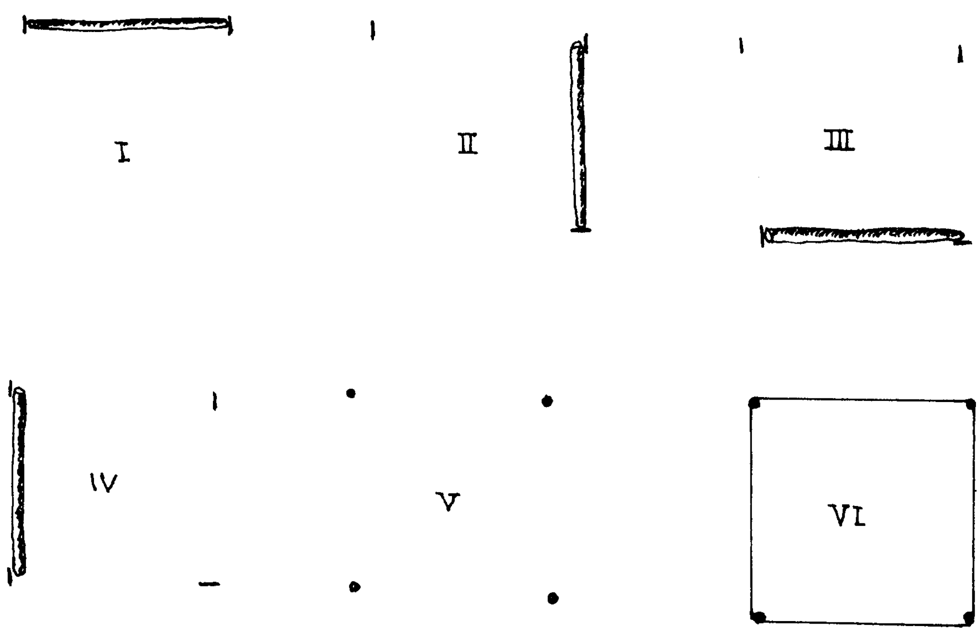


Fig. 6.2 (I, II, III, IV, V and VI): square base construction

However, the way the vertices are obtained, by trial and error, and the intuitive manner to obtain the right angles led the house builder himself to doubt that the obtained quadrilateral is in fact a square.

The only builder who used this method said, answering one of the researcher's questions, that one can ensure that the obtained quadrilateral is a square (Fig. 6.2.VI) by using another rope. With this rope, like in the first method, one measures the distances between opposite vertices and compares them. If the distances are equal then the quadrilateral is a square.

However, perhaps because of the age of the interviewed builder (only 13 years old), who learned this method from his uncle, the researcher did not have the possibility to see how one can proceed further in case to make adjustments if the distances between the opposite vertices were different. It was not possible to interview the uncle.

*This construction method reflects the knowledge that a quadrilateral with four equal sides and right angles is a square. However, the way the vertices are obtained, by trial and error as a result of the intuitive manner to obtain the right angles, leads one to say that this method is not very efficient. The house builder who used this method was also aware of the limitations of this method and that can be viewed as a proof that he knows what, in fact, a square is. (*See interview transcription in the appendix -- Interview Zambezia-2.*).*

At the end of the interview the house builder said that one could ensure that the obtained quadrilateral is a square by measuring and comparing the distances between opposite vertices. Can that be a demonstration that he, or his uncle, has the knowledge that a quadrilateral with four equal sides and equally long diagonals is a square and that a rhombus is not a square?

6.1.2c) The third method

The researcher found no one who used this third method, although some builders spoke about it.

According to them, the house builder starts by laying down two long sticks of equal length on the floor and more or less parallel (Fig. 6.3.a). Then he combines the first two sticks with two other sticks, also of equal length, in order to form a quadrilateral. Now he adjusts the sticks further until all angles are right angles -- measured by a square (Fig. 6.3.b). He measures all four angles (according to the informants who don't use that method). The standing figure is the base of the future house (Fig. 6.3.c).

Fig. 6.3.a

Fig 6.3.b

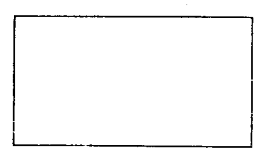


Fig. 6.3.c

One of the informants was a house builder who uses the first method and had this to say about this third method :

> Even if I had a set square, I would continue to use a rope *(to measure and compare the diagonals).* It is a very quick method to determine a rectangle. While with the (set) square one has to measure the four angles several times and adjust the sticks until one gets it right. With a rope one can put it right in an instant, and when one takes a square one can quickly confirm that all angles are right angles. (Interview from 05/07/97 -- Interview Zambézia-1).

Therefore, this shows that this builder defends his method, the first method, as the best one. However, two years later (in a short interview from April/99) he changed his position. This time he (Sualé) was looking more carefully at other house builders who were using a (set) square and saw that it was easier to obtain the rectangular shape using a square than using a rope. But, he said again that he will continue to use a rope because it was always easy to find or make a rope.

This method shows us the knowledge that when the angles of a quadrilateral become right angles, the quadrilateral becomes a rectangle. However, it would not be necessary to check all four angles, knowing that the quadrilateral has already equal opposite sides (sticks).

By analysing this method one has also to consider that one couldn't interview a builder who used this method. Perhaps a house builder who often uses this method could measure only one or at most two angles. By the second interview one of the informants was not able to explain how the other house builders use a square, but was only able to tell the researcher that it was easier to use it to obtain the rectangle. This approach is an indication that there might be a slow movement away from strict traditional methods.

In Sofala Province four different methods were prevalent, which in the thesis are designated as the fourth, fifth, sixth and seventh methods.

6.1.2d) The fourth method

The house builder who had told us about the fourth method was at that time preparing the construction of a small square-based house (granary) to store maize. He said that each side would measure four *armfuls* (See also in Murimo, 1997, pp. 1A-6A.)

He took a long rope, measured on it four *armfuls* and tied a knot in the rope at the point corresponding to the length of four armfuls. He laid down the rope on the floor and pinned the first endpoint of the rope -- from where he began to measure -- in the ground with a small stick. Then he stretched the rope and also pinned in the ground the tied knot with a small stick. Next, he measured again four armfuls from the remaining rope and tied a knot. After that the builder stretched the rope forming an approximate right angle with the part of the rope already fixed on the floor pinning the knot in the ground. So, he repeated the previous step, always with the objective that a square results on the floor, formed by the rope. After obtaining the quadrilateral he took another rope, measured with it the distance between two opposite vertices and cut the piece of rope corresponding to that distance (Fig. 6.4.a). Afterwards the builder compared the length of this rope with the distance between the other two opposite vertices of the quadrilateral. He saw that the rope was shorter than the distance between the other opposite vertices (Fig. 6.4.b).

Soon afterwards he changed the positions of three vertices of the quadrilateral (Fig. 6.4.c) and measured and compared again the distances of opposite vertices. This process was repeated until the diagonals became equal. However the figure was no longer a square with a side measuring four armfuls, but a strict rectangle, with the sides measuring less than the planned four armfuls.

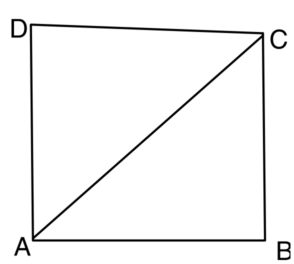


Fig. 6.4.a

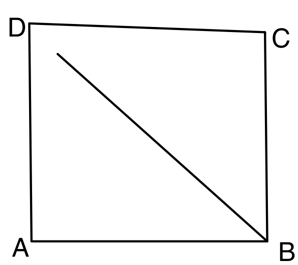


Fig. 6.4.b

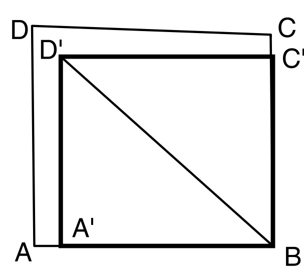


Fig. 6.4.c

During an interview the house builder could recognize that this method is very complicated and therefore, it was difficult to obtain the square with the desirable dimensions.

This construction method had reflected the knowledge that a quadrilateral with four equal sides and equally long diagonals is a square. However, the way the vertices are obtained, by trial and error, and the intuitive manner to obtain the right angles leads one to say that this method is not very efficient when not well used. Comparing this method with the second -- in which the right angles are likewise decided intuitively, by eye -- this method (the fourth) is more efficient than the second method because, whereas by the second method the sides of the quadrilateral disappear when the position of the stick is changed, by this method the sides are materialized with the rope. In order for the quadrilateral to become a square with the desired dimensions, one needs only to change the positions of the vertices without changing the length of the sides.

The mistake of the interviewed house builder was that he changed the positions of the vertices and at the same time changed the lengths of the sides of the quadrilateral. In that way, one could even land into an isosceles trapezium, given that an isosceles trapezium is a quadrilateral with equally long diagonals. But, would this last comment take the merit away from the house builders who consciously use that method?

6.1.2e) The fifth method

To construct a rectangular/square base using the fifth method the house builder needs 12 small sticks, a very long rope and a (set) square. (See also in Murimo, 1997, pp. 1B-8B.)

The house builder pins the stick **A** on the ground and ties on it one of the endpoints of the rope. Next he stretches the rope according to the already imagined measurements of the sides of the house to be built and pins the stick **B** on the ground. Then he rolls up the stretched rope around this stick. After that he pins on the ground the sticks **C**, **D**, **E**, **F**, **G** and **H** according to the sequence shown in Fig. 6.5.a, and continues to stretch the rope up to the stick **A** again, always trying by the naked eye to obtain with the rope a quadrilateral with four right angles.

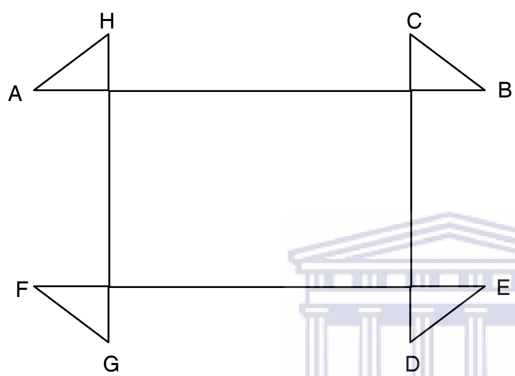


Fig. 6.5.a

After that he pins the sticks **I**, **J**, **K** and **L** on the ground in the points where the rope crosses itself (Fig. 6.5.b). These four last pins can determine the four vertices of the house to be built.

However, the process does not end here as it is necessary to check if obtained quadrilateral is, in fact, a rectangle.

The house builder introduces the following step as “to correct”. The process in this step he checks with a set square if the angles $H\hat{I}J$, $I\hat{L}K$ and $J\hat{K}E$ are right angles. He verifies only three angles. After verifying the angles and after making possible corrections,

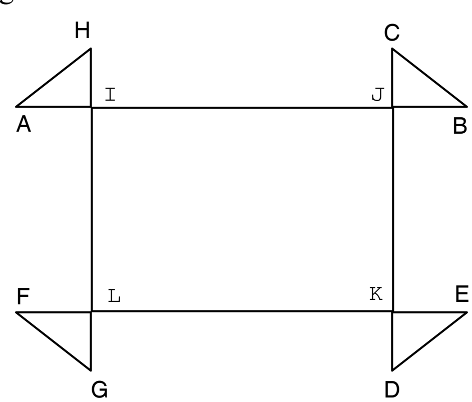


Fig. 6.5b

the house builder finally measures two consecutive sides of the quadrilateral and compares the result with the previously planned measurements. He measures simply two consecutive sides of the rectangle. If necessary he changes the position of some sticks and does new measurements of the angles and sides afterwards.

This construction method can reflect the knowledge that a quadrilateral with three right angles is a rectangle. The lengths of the sides of the quadrilateral are not exactly known, so one needs to ensure that at least three angles are right angles to obtain a rectangle, otherwise the quadrilateral can become any quadrilateral or even a trapezium. Is the house builder also thinking like that? Or is that a result of a routine work? Why could this routine work be done exactly like that? – Mere coincidence?!... or "geometrical" knowledge?

6.1.2f) The sixth method

To construct a rectangular base, using the sixth method, the house builder needs a very long rope, four short sticks, a steel tape and a set square.

The house builder pins the stick **A** into the ground. He ties the short stick on one endpoint of the rope and stretches the rope on the ground and measures with a steel tape. Where the measurement ends he pins the stick **B** and ties the rope to it. Then he stretches the remaining part of the rope changing the direction of it in a right angle using the square.

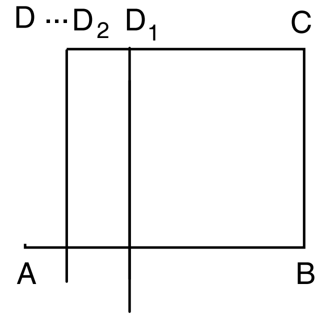


Fig. 6.6a

From the point where the direction of the rope was changed the house builder measures it with the steel tape and reaches the point where he will pin the stick **C** into the ground and tie the rope.

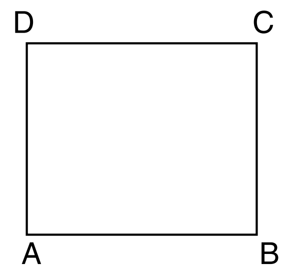


Fig. 6.6b

Using the setsquare, without measuring the length of the remaining rope, the house builder pins the stick **D** into the ground (D_1 in Fig. 6.6a) and changes the direction of the rope stretching it back to the stick **A**. If the rope does not go through the stick **A**, the house builder changes the position of the stick **D** (see positions D_1, D_2 ... in Fig. 6.6a), using the set square again and stretches the rope in the direction of the stick **A**.

Next the house builder measures again the sides AB and CD and compares both lengths that had to be equal. The lengths of the sides BC and AD had to be equal too. If these sides do not appear to be equal, it means that the base is not perfect, i.e., the base is not rectangular.

So the house builder has to change the position of the stick **D** again and, at the same time, verify if the angles $B\hat{C}D$ and $C\hat{D}A$ are right angles. After that the house builder measures the sides again and compares the lengths of opposite sides. When the sides finally become equal, then the rectangular base of the house is ready (Fig. 6.6b).

The house builder who was interviewed said that this method can be used without a set square by determining the right angles through approximations by (the naked) eye. Afterwards one begins to adjust the stretched rope in order to obtain equal opposite sides and equal diagonals. But he said emphatically that one can take all day without obtaining these equalities, in contrast to what happens when one uses a set square or *carpenter's square*.

This construction method reflects again, like the fifth method, the knowledge that a quadrilateral with three right angles is a rectangle. The rectangle appears when one translates a parallel straight segment to the side ***BC*** *(or the segment BC itself), according to the vector* $\overrightarrow{BA}$ *until the point* ***A*** *belongs to the translated straight segment. At the same time the point* ***D*** *is determined.*

The interviewed house builder who used this method is aware of the difficulties that one can have when the fourth method is used, then this sixth method can be seen as an improvement of the fourth method, however, this time the "right" angles are not determined by eye, but with set square.

6.1.2g) The seventh method

To construct a rectangular base using the seventh method the house builder needs a very long rope and two relatively short ropes, four short sticks and a set square. First the house builder pins the sticks A and B into the ground. Afterwards he ties one of the endpoints of the first rope (the very long one) on the stick A and stretches it between the sticks A and B and ties it on the stick B (Fig. 6.7.a). Next he stretches the remaining part of the first rope, changing the direction with the help of a square. At certain distance he ties the rope on the stick C, according to the desired length of the side of the future house (Fig. 6.7.b).

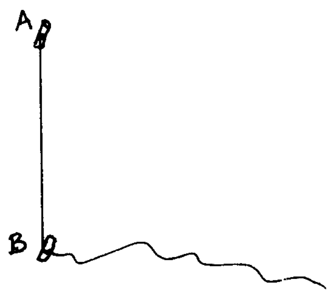


Fig. 6.7.a

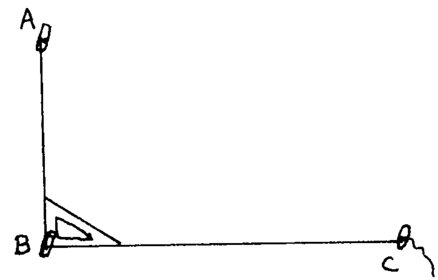


Fig. 6.7.b

Then he takes one of the short ropes and measures from the stick A to the stick B and ties the endpoints of it to the sticks A and D *(the rope between the sticks A and D has the length AB)*. After that he takes the second short rope and measures from the stick C to the stick B and ties the endpoints of it to the sticks C and D *(the rope between the sticks C and D has the length BC). Notice that at this moment the stick D is lightly pinned near the stick B*. Finally he takes the endpoint of the short rope tied on the stick A and ties it on the stick C and the endpoint tied on stick C to the stick A, stretches both short ropes and pins the stick D into the ground (Fig. 6.8). So, the four sticks pinned into the ground and the stretched ropes determine the rectangular base of the house to be built.

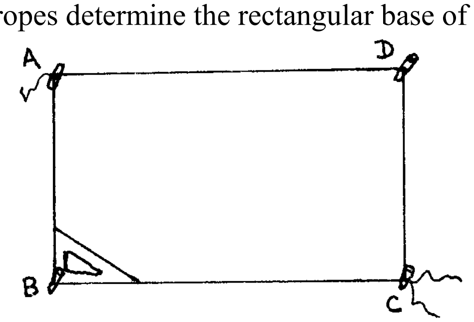


Fig. 6.8

This construction method reflects the geometrical knowledge that the rectangle is a geometrical shape with a right angle and central symmetry. It is clear that the house builder does not use the centre of the figure -- the point of intersection of the diagonals -- but the idea of central symmetry is hidden in the *movements of the ropes and stick D. Is this method a “by chance” product, or of an empirical constructed knowledge?*

6.1.2h) The eighth method

This method was found only in the literature, by Gerdes (1991, 1998 and 1999). According to Gerdes (1991) this method and the one presented as the *first method* are common among the Mozambican peasantry for the construction of the rectangular base.

This method was not to be incorporated in this study given that it was not found during the fieldwork in Sofala and Zambézia Provinces. But, given that it is a rectangle construction method used in Mozambique it is included in this study for two main reasons: (1) to encourage Mozambican readers to use it in practice; and (2) to include the method in a study where, for the first time ever, more than three methods -- in this case eight -- used by Mozambican peasants to determine the rectangular base of a house are presented together.

Using this eighth method the house builder starts "with two ropes of equal length, that are tied together at their midpoints". (Gerdes, 1991, pp. 64-67) (fig 6.9.a)

> A bamboo stick, whose length is equal to that of the desired width of the house, is laid on the ground and at its endpoints pins are hit into the ground. An endpoint of each of the ropes is tied to one of the pins. (Gerdes, 1991, pp. 64-67) (fig 6.9.b).
>
> Then the ropes are stretched and at the remaining two endpoints of the ropes, new pins are hit into the ground. These four pins determine the four vertices of the house to be built. (Gerdes, 1991, pp. 64-67) (fig 6.9.c).

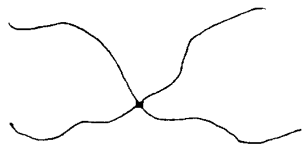


Fig. 6.9.a

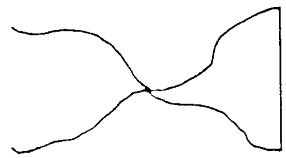


Fig. 6.9.b

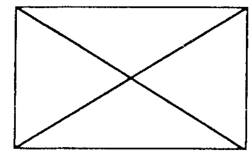


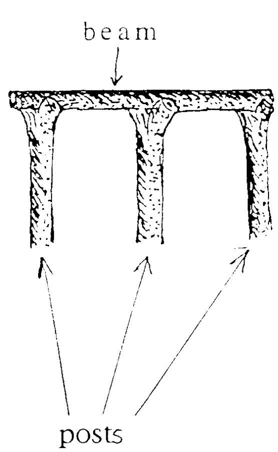
Fig. 6.9.c

This construction method (found by Gerdes in Cabo Delgado Province*) *had to reflect the geometrical knowledge that a quadrilateral with diagonals of the same length that intersect each other in their midpoints is a rectangle.*

(* Information given informally by Prof. Paulus Gerdes in May 2003.)

6.2 Placing the posts and beams

In this section is a description of how some house builders place posts and beams (Fig. 6.10) if the base of the house is rectangular. A first survey of mathematical knowledge involved will also presented but for the time being the question of what mathematical aspects are used consciously by the builders will be put aside.



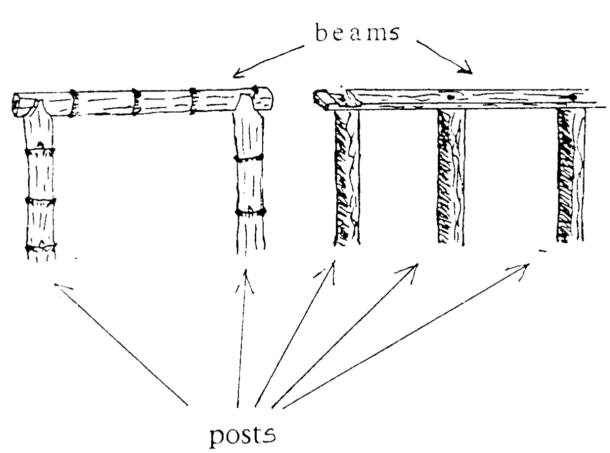


Fig. 6.10 (posts and beams)

This description resulted from direct observation, interviews with some builders of traditional houses and a reflection done afterwards about these observations and interviews with *Echuwabu* speaking builders in the southern region of the Mozambican province of Zambézia and *Cisena* speaking house builders from central and northern regions of Sofala Province.

6.2.1 Placing the posts

Having determined the rectangular base of the house, the builder marks the positions where holes should be made for the posts. After this, the arrangements made for the rectangular base are removed and the builder digs the holes to the necessary depth. In order to place the first post upright, the builder needs the help of an assistant that can be an apprentice, who has to carry out the builder's instructions.

6.2.1a) First posts placing method

This method is used both by house builders from Zambézia Province and by house builders from Sofala Province.

The first post having been put in its hole, the master takes a position at a certain distance and, turning to the post, he examines that the post is not inclined neither to his left nor to his right side. In order to do this, he looks a number of consecutive times to the base and the top of the post, always glancing over the whole post with his eyes (Fig. 6.11.a). If necessary, he orders the assistant to *incline/push* the post more to the left or more to the right. When he thinks that the post is well upright, he fixes it in the hole from the left and from the right side. Next, he takes a new position, in a direction to the post that is approximately perpendicular to the former direction (Fig. 6.11.b).

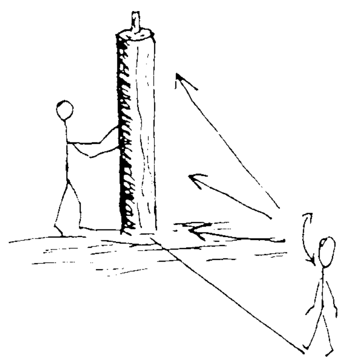


Fig. 6.11.a

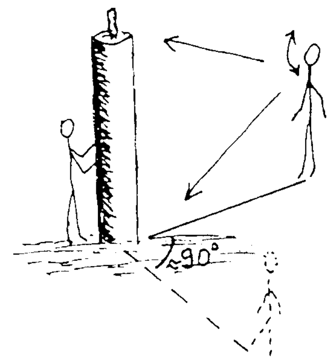


Fig. 6.11.b

As before, he makes sure the post is not inclined to his left or to his right side. After having requested the straightening of the post in a given direction, he returns to his former position because he wants to check whether the post has not been exposed to a deviation in the other direction. Finally, he orders the post to be *fixed* in its hole. This process is repeated for the other three corner posts of the house in construction.

Sometimes two different persons are take the two positions at the same time and both give orders to the assistant.

In short one can say that it is possible to imagine that the builder looks to the post as were it a straight line that should be perpendicular to the plane of the ground. So the post should be the intersection of two planes perpendicular to the plane of the ground and therefore the post should be perpendicular to at least two straight lines in this plane, which are the intersections between both planes with the plane of the ground (Fig. 6.12). *So as one knows from stereometry, the post can be considered as perpendicular to the plane of the ground because it is perpendicular to two straight lines of this plane. Otherwise, the post can be seen* *as staying in the intersection of two planes, α and β, perpendicular to the ground.*

As the builder is working on a not completely flat ground using his naked eye, he chooses two positions which are almost perpendicular to each other, that will enable him to make fewer verticality mistakes.

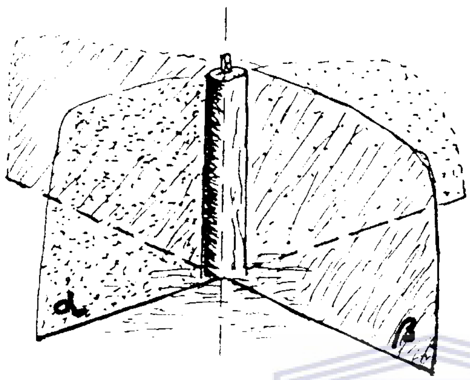


Fig. 6.12

6.2.1b) Second post's placing method

This method was found only a few times and only by house builders from Sofala Province, but it does not mean that it is not used in Zambézia Province. Using this method the house builder will need the help of an assistant. The post is put in its hole. The house builder takes a position face to face with the post and holds it upright. He looks to the top of the post in order to examine if it is not inclined to his left or to his right side. If necessary he pushes the post more to the right or to the left (Fig. 6.13a). When the house builder thinks that the post is well upright he requests the assistant to fix it in the hole from the left and from the right side while he keeps it up upright. Afterwards, he takes a similar position in a direction that is approximately perpendicular to the former position. (Fig. 6.13b)

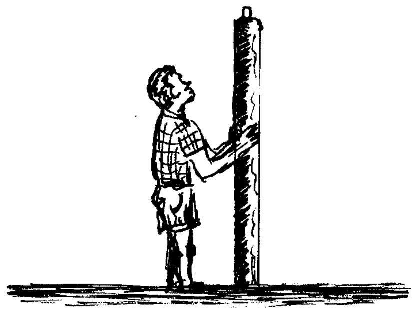


Fig. 6.13a

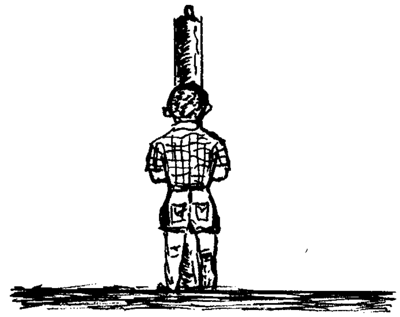


Fig. 6.13b

As before, from this new position, he makes sure that the post is not inclined neither to his left nor to his right side. After having ordered to straighten the post's position in the direction of the position he has taken up, he returns to his former position because it is necessary to check whether the post has not been exposed to a deviation in the former direction. Finally, he requests the assistant to fix the post in the hole.

Both these methods are based on perpendicularity of planes in space. But this last method has a disadvantage when very thick posts are used. In fact, using this second method with a thick post, when one looks at the top of the post standing up near to it, it is difficult to determine if the post is upright or not.

6.2.2 Placing the beams

The way of placement of the beams varies in accordance with the type of posts used in the house construction. To ensure if a beam is well placed, i.e., the beam is in a horizontal position, the researcher found two methods used by the *Echuwabu* speaking house builders. First, the three types of posts used shall be distinguish and then a description of the way of placing the beams will be given.

A presentation of the two methods that are used to ensure horizontality of the beams will also be done.

a) a post made of a small, not very smooth tree trunk or branch, or forked post;

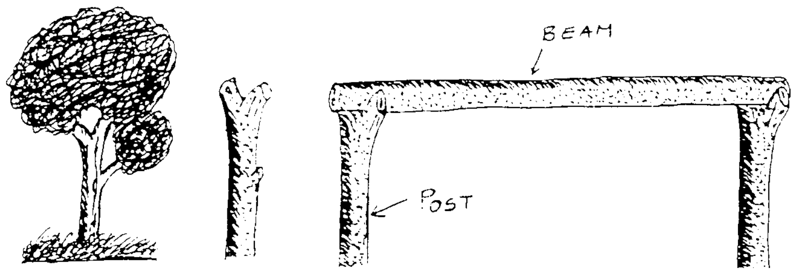


Fig. 6.14

b) *a post made of bamboo;*

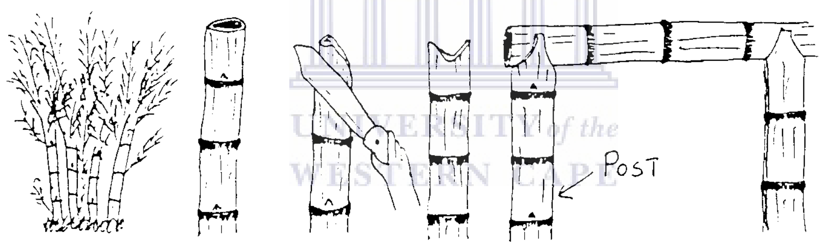


Fig. 6.15

c) a post made of coconut tree timber or other well worked timber.

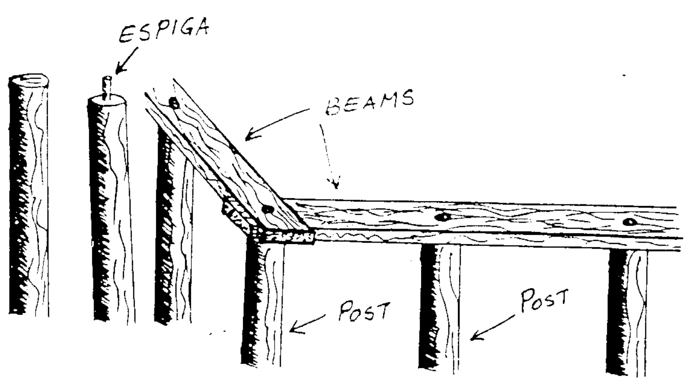


Fig. 6.16

First, the researcher shall present the placement of beams when *posts made of a small, not very smooth tree trunk or branch* (type a) are used. To have posts of this type one must choose a straight tree steam or tree trunk, with the necessary length, which must have a form of V in one of its ends after cutting it (Fig. 6.14). This part with the form of V (or fork) -- *nipatha,* in Cisena and *nipada,* in Echuwabu -- will be chosen to be the top. This *nipatha* will give stability to the beam on the top of the post.

When posts of this type are used, the rectangular base of the future house is constructed using rope, sticks or whatever wooden pieces, but not using the heavier beams. After having placed the corner posts, the first two beams to be placed are the opposite ones (Fig. 6.17.a). This sequence of placing beams brings stability for the to-be-placed other two beams and has as advantage of the maintaining the horizontality of the other four heavier beams (Fig. 6.17.b).

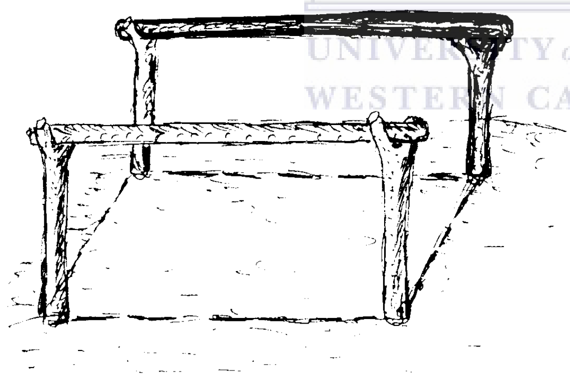


Fig. 6.17.a

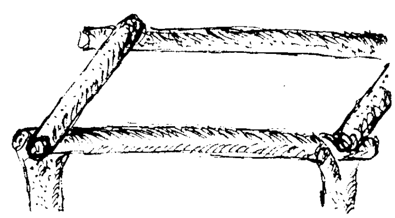


Fig. 6.17.b

Secondly, the researcher is going to discuss the placement of beams when posts of **type b)** are used.

A *"ripe"* bamboo is selected and cut into parts with the desirable length for the posts. Next, the side chosen to be the top of the post, which in general is the *slim* part, is worked on in order that a V form appears (Fig. 6.15). The sequence of placing beams using posts of the **type b)** is similar to those for post of **type a)**.

Finally, he shall discuss the placement of beams when posts of **type c)** are used. This type of posts is made of coconut tree timber, mostly in Zambézia Province, or another type of timber like *umbila*. One takes timber between 7,5 and 15 cm thick and long enough for a house post and one works on it to form cylindrical posts. Next, the side chosen to be the top is worked on in order that in the middle remains a small stake which the builders name *espiga* (spike or pin) (Fig. 6.16). This *espiga*, a small cylinder on top of every post, will be fitted into a hole of about the same diameter as the *espiga*, drilled in the beam. The *espiga* is about as long as the beam is thick.

When posts of type c) are used, the rectangular base is plotted directly by means of the superior beams of the future house and not by means of sticks or whatever wooden pieces.

After the beams have been well arranged to form a rectangle (using the first or the third method of rectangle construction), the builder marks the spots that will be occupied by the posts, immediately on the beams. Next, the builder drills small holes in the beams (using hammer and chisel), where the *espiga* of the posts should be fitted in. All the holes in the beams are made as the beams are still forming the base of the house. Next, the builder pins small sticks into the ground through the holes in the beams. When all holes have their sticks, the builder and an assistant take the beams away. In the next step, the builder removes the small sticks from the ground, one by one. Instead of every stick he digs a hole for a post.

After the corner posts have been placed it is time to place the beams one by one. Having placed the first beam, which is the stick or the timber that goes from one corner post to the post placed at the next corner, the builder withdraws and takes his stand at a point that could be said to lie approximately on the perpendicular bisector of the segment between the posts supporting the beam (Fig

6.18). He looks several times from one end of the beam to the other and in this way he is able to decide whether the beam is horizontal (*oguaguanyea* = to lie well down) or whether one end is more upwards (*owela* or *owelela* = rise) or more downwards (*oquita* or *oquitela* = go down). At the same time he checks whether the beam is at the right height for a house of the size he wants to build. If there are deficiencies, now is the time to do something about it.

Fig. 6.18

This procedure makes one think that, the house builder imagines a horizontal line through the top of one post and another line, also horizontal, through the top of the other post. If the two lines meet, they will pass through the beam and in this way the builder may conclude that the beam is well placed, that it is horizontal. As Ascher and Ascher (1997) write and also in agreement with the researcher that, “the idea of a straight line is intuitively rooted in the kinesthetic and the visual imaginations”. (Ascher and Ascher, 1997, p. 36).

Given that each hole in the beam (for the espigas) corresponds to a hole on the ground (for the posts) it is gauranteed that the beams of each wall will stay parallel each other. Remember how the holes on the ground and on the beams are made!

If the beam is very long, for a very big house, another post is placed at about the middle of every side (wall) of the future house, before the beams are placed (Fig. 6.19). This is to avoid bending or sagging of the beam and consequent inclination of the corner posts to the middle of the future house.

The builder knows that a beam can bend down or sag under its weight, be it as straight as it may, if it does not satisfy the horizontal condition through its ends, and then it will incline the posts that support the beam at the ends and it will make the decision difficult whether the posts have the same heights or not. (Fig. 6.20).

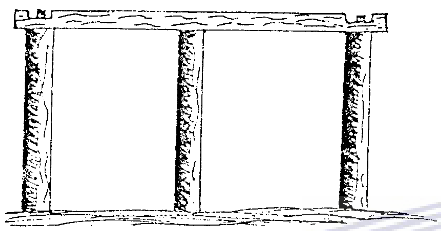


Fig. 6.19

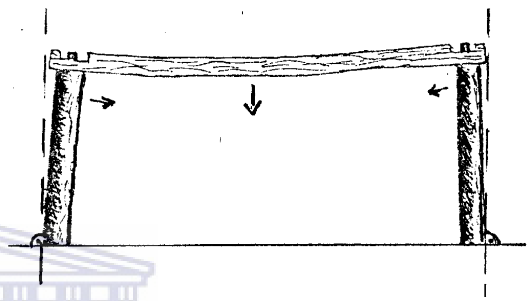


Fig. 6.20

Even though there is evidence that the house builder, in this situation, is showing geometrical and physical knowledge or intuitions, one may wish to argue that some 'mathematical sense was unearthed through the building process..

The second method that is used to ensure that a beam is well placed consists of comparing the height of the beam near to both corner posts with the length of a previously prepared stick with a desired height for the beam (fig. 6.21.a and 6.21.b).

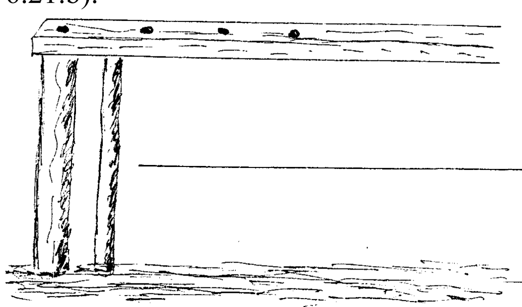


Fig. 6.21.a

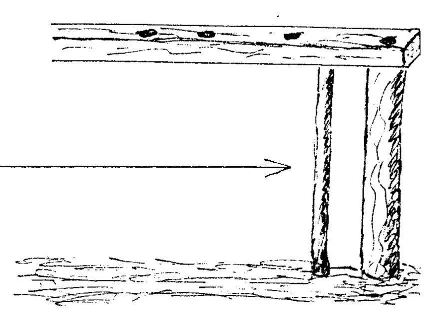


Fig. 6.21.b

At this point, the remaining posts are placed ad the alignment of the remaining posts is done in a single direction. The builder takes a stand at some distance of the construction site, at a point that he only sees one post when looking to two posts at consecutive corners. Then he requests his assistant to align the intermediate posts such that they belong to the plane defined by the two corner posts, and such that at the same time, the beam of the wall concerned fits around the *espigas* of the posts.   In order to achieve this, it is necessary to lift the beam slightly, perhaps many times, such that the *espiga* of every post is inserted in its respective hole in the beam. In the other direction, perpendicular to the future wall, the posts of the type one is talking about are all forced by the *espigas* in a parallel position to one another (Fig. 6.22).

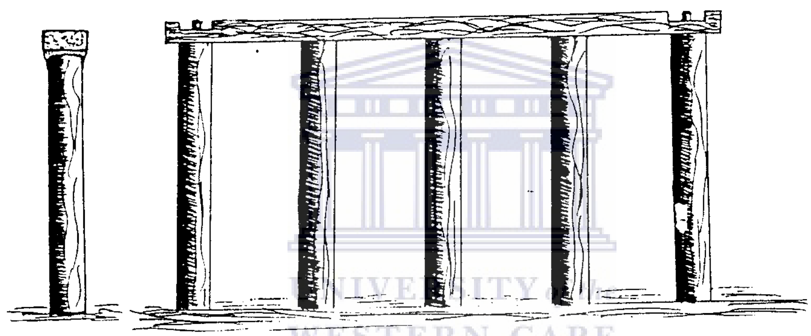


Fig. 6.22

So, if one ascertains that the corner posts are vertical, then the intermediate posts will be so too. Having placed all beams and posts, the builder has to stand at a certain distance of the construction site looking frontally at every wall. This is in order to check if the process of placing the beams inclined some of the initially vertical corner posts to one side or another.

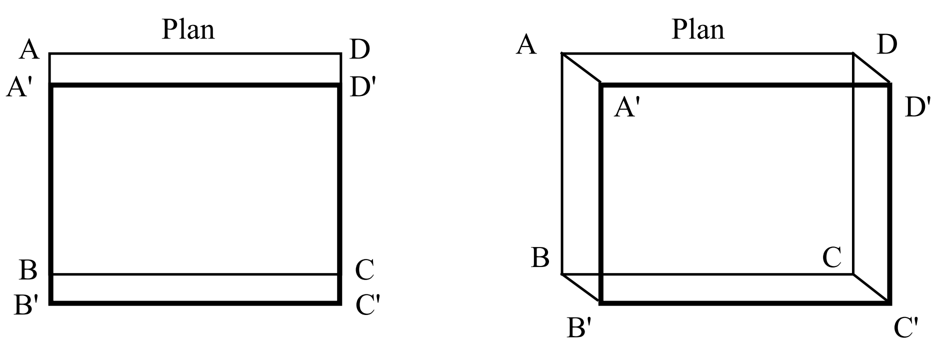
Provided the corner posts have been placed vertically, the other posts can only incline to the outside or to the inside of the wall and this does not happen frequently.

6.2.2.1 Some mistakes in placing the beams

After placing all beams and posts the house builder takes position at certain distance from the construction site facing each wall in order to check if the ~~check if during the process of placing~~ beams were placed properly and that the remaining posts, some corner posts, which are suppose to be vertical, are not inclined to the sides. The house builders of Southern Zambézia classify the mistakes which can occur in this phase of house construction process into different categories and the following two are discussed.

6.2.2.1a) *Otedemana* — to be inclined

This defect is characterised by the fact that during the placement of the beams the house is forced to an inclination in the direction of one of the walls or in the direction of one of the diagonals from the base or, in addition, these two situations combined, however maintaining the rectangle or square formed from the four beams. (Fig. 6.23)



(AA', BB', CC' and DD' are posts, and bold lines are beams.)

Fig. 6.23 (*otedemana*)

When this mistake (*otedemana*) occurs the house builders say that the house is *not beautiful (otakala)* or that the house *is fallen (egwa).* They use the term *otedemana* only when they want to explain what it means for a house to be *otakala* or *egwa.* Depending on the grade of the inclination a house which is *otedemana* can even so be completed and one can live in it. But sometimes it is possible to correct the defect before completing the house building. The house builder who builds an *otedemana* house loses his reputation among other house builders and also among ordinary people.

6.2.2.1b) *Orintea* — to be twisted

This defect consists of the rectangle or square formed by the beams to be exposed to a rotation in relation to the rectangle or square from the base, during the placement of the beams, or to be exposed to a transformation so that the rectangle formed by the beams becomes a non rectangular parallelogram. (Figures 6.24.a and 6.24.b)

On the plan below the posts DD' and AA' are inclined. The rectangle formed by the beams was exposed to *orintea.* It is like the points D and A turned round the points C and B, respectively, according to the same angle.

On this plan one can see that the structure of the house suffered *orintea.* It is like the rectangle formed by the beams rotated round the crosspoint of the diagonals. This defect is sometimes combined with a translation.

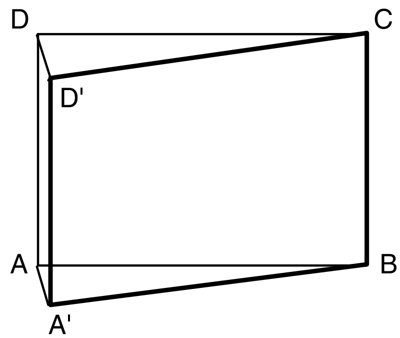


Fig. 6.24.a

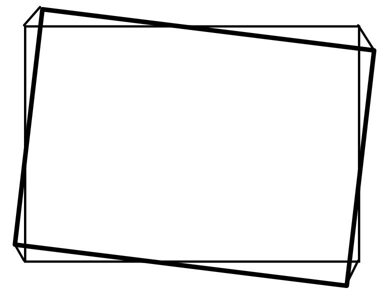


Fig. 6.24.b

So, after placing the beams a reliable house builder verifies once more the structure of the house in order to check if the house is in the vertical position and provides all actions so that it can be, before placing the roof. The roof can be placed or constructed before or after the complete construction of the walls. In this study the researcher will refer the case in which the roof is placed after the construction of the walls is complete. Then his objective is to refer to the roof in another point of this study.

6.3. Construction of the walls

When all beams are placed, the house builder begins to tie small sticks in the horizontal position, from top to bottom (Fig. 6.25) on the outside. Those sticks -- battens -- take the names *balilo*, in Echuwabu and *mbalilo*, in Cisena. These two expressions have no special meaning outside the context of traditional house building. The house builder takes a row of *balilo* and makes a full turn through the four walls. The rows are separated by a distance of approximately a hand span. Mortars (see Fig. 2.3), drums, chairs and tables are used as scaffoldings in traditional house building.

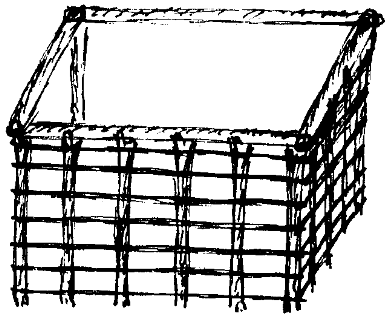


Fig. 6.25: Walls with mbalilo (battens)

The separation of the (m)balilo rows by a hand span can be seen as a sign that the house builder has a clear idea about parallel line segments.

After the placement of *mbalilo* follows the phase where the spaces between the posts must be filled vertically, also with small sticks tied to the mbalilo, on the inside. Those new sticks are called *ntchintchi,* in Cisena and *kokotelo,* in Echuwabu. These sticks are tied in the vertical position, one with the slender or thinner part pointing to the top and others with the slender part pointing to the bottom, so that each space between two posts becomes well fitted. *Kokotelo*, in Echuwabu, is connected to the verb *okokotela*, which means, in mathematical language, *to make continuous,* without interruptions. In this process, one or two spaces between posts of opposite walls will remain unfilled, where doors will be placed. The spaces for windows are opened later. Finally, *mbalilo* are tied on the inside of the future house. After that, what can also be done after the roof is thatched, during the rain season, the walls are covered by hand with a very well selected mud, that must be very adhesive, while humid, which becomes very hard, when dry. That is always done when the doors are already fitted in.

The process of covering the walls with mud consists generally of four stages. In the first stage the walls are covered on the inside. When the mud is nearly dry the walls are covered on the outside. After some days the walls are covered again with a second coating of mud on the inside and one can smooth the walls while the mud is wet (*kunzira*, in Cisena and *ozirima*, in Echuwabu). The same is done on the outside. The whole process of covering the walls with mud is called *kunama*, in Cisena, and *omatika*, in Echuwabu. The same words are used with the meaning of *to put something on the top of something*, and to emphasize the process one uses also the word *omatikela*, instead of *omatika.*

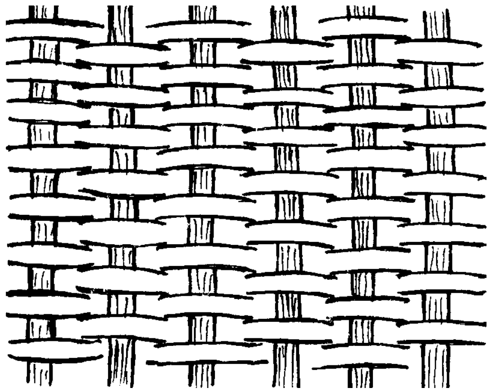
Omatikela or omatika, that means to put something on the top of something *is a very important process in the first stages of learning of geometry, for example, by comparing surfaces of plane figures without calculating the areas.*

Only looking at the walls the house builders can estimate the necessary volume of mud for covering (omatika) the walls.

Children at school can compare the surfaces of plane figures putting a figure above the other.

According to ARPAC's findings earlier, in Sofala Province, one used to beautify the house walls with geometrical figures and animals with mud of different colours. But now the houses, at least the observed houses, have no decorations. However sometimes a black band near the floor/base, on the outside of the house wall is used as decoration. The 16 years of civil war in Mozambique can be seen as the reason for the end of the custom of decorating the house walls in Sofala Province.

In the districts of Nhamatanda, Gorongosa and Maríngue of the Sofala Province, the kitchen and granary walls can be made of bamboo strips as shown in figure 6.26. The kitchen wall can be covered with mud, especially on the inside, in order to avoid fire disasters. This technique can be used both for cylindrical and for rectangular walls. This wall construction technique can also be seen in the book by Denyer (1978, p. 100)



Wall of bamboo strips (*Drawing by the researcher*)

Fig. 6.26

6.4. Construction of the roof for rectangular based houses

After all beams and posts are placed the house builder begins to construct the roof. Sometimes the roof is constructed when the walls are already completed.

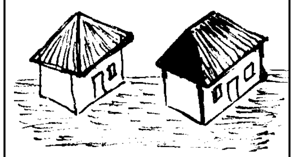
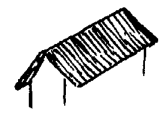
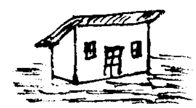
Here the author will deal with the construction of two different four-sided roofs and the construction of a two-sided roof.

6.4.1 Classification of traditional houses according to the roof type

According to the Echuwabu speaking house builders from the Zambézia Province, houses with a rectangular base can be classified into three categories according to the roof form.

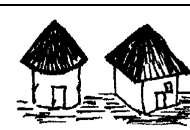
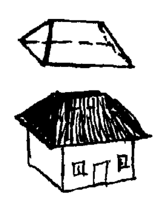
Table 6.1: Classification of traditional houses according to roof type by Echuwabu speaking house builders

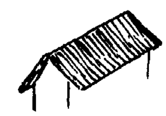
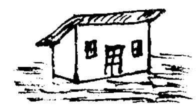
Classification	Characteristics	Bases type	Illustration

1. ***Ya mapara manai***	Roof with the form of a pyramid or of a distorted triangular prism.	Squared or rectangular	
2. ***Ya mapara meli***	Two-sided roof	Rectangular	
3. ***Ya nipara nimodha***	One-sided roof	Rectangular	

The Cisena speaking house builders from Sofala Province classify the houses according to the base type and according to the roof type. In the next chapter the classification of traditional houses by the Cisena speaking people will be revisited in order to include classification according to base type, size and/or usage. The classification appears in Table 7.1. Further elaboration on classification by usage only also appears in the next chapter, in Cisena and in Echuwabu. As regards the roof type one found among the house builders of Sofala Province five house classifications according to Table 6.2.

Table 6.2: Classification of traditional houses according to roof type by Cisena speaking house builders

Classification	Characteristics	Bases type	Illustration
1. ***Nsukuli***	Roof with the form of a cone or squared pyramid. This last one is sometimes called ***nsukuligóngwè***	Circular or square, but not rectangular.	
2. ***Góngwè*** *or* ***magóngwè***	Roof with the form of a distorted triangular prism for houses with "big" ratio between length and width.	Rectangular, not squared	

3. *Nhama-góngwè*	Roof with the form of a rectangular pyramid.	Rectangular, not squared	
4. *Ramada* or ***nsana wa ndzou***	Two-sided roof *Nsana wa ndzou* in Cisena means *elephant's spine.*	Rectangular	
5. *Nkhope ya kolo*	One-sided roof, often inclined to the back side of the house.	Rectangular	

Nsukuli is the type of roof used on houses of square and circular base. So, roof with the shape of right square pyramid or cone. After some analysis one came to the conclusion that the designation *nsukuli* is originating from the word *SUKULI* or *nguli,* which means "top" a kind of toy for children. (Fig. 6.27)

Fig. 6.27 Sukuli = "top"

It is easy to see the similarity between the roof of a house of circular base (cone) and the toy top. *But, why does a right square pyramid take the same name?*

The researcher will try to answer this question in chapter 7.

Fig, 6.28: House of *nsukuli* type with square base, Nhamatanda – Sofala Province

Góngwè or *Magóngwè* is a type of roof which seems to be a geometrical transformation of a triangular prism. It is used on houses of rectangular base when the ratio length/width is big (≈≥ 1,4). For example:

House A: length = 7m, width = 5m (ratio = 1,4)

House B: length = 5m, width = 3m (ratio = 1,7).

House C: length = 10m, width = 7m (ratio = 1,4)

Originally ***góngwè*** *meant* **house of big dimensions***, independent from roof type. But, as the most common roof type used in big rectangular based houses is the one which is described above, consequently, in our days, independent of size, a house with that type of roof is called* ***góngwè*** *or* ***magóngwè.***

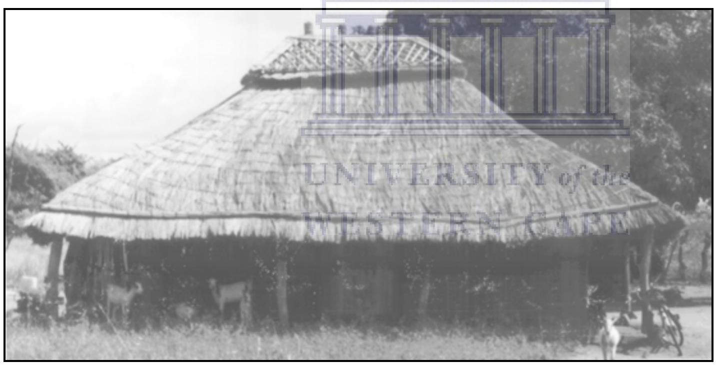


Fig. 6.29: House of *góngwè* type, Caia – Sofala Province

Nhamagóngwè is the name given to a roof with the form of a pyramid when it is made over a house of rectangular base, not squared.

Originally the name Nhamagónwè is not related to roof type, but to the form of the box formed by the walls. Nhamagongwe originally means rectangular parallelepiped. Nhamagongwe is the name given to a form of a can in which Portuguese olive oil was packed, with the form of a rectangular parallelepiped.

Ramada for the house builders in Sofala Province is a house of rectangular base with two-sided roof. But for the Echuwabu speaking house builders from Zambezia Province *ramada* is any provisional house independent of the roof type. For the Echuwabu speaking house builders ramada has generally walls made by grass, straw or coconut-leaf mats, called *magadji* (singular: *nigadji*) and with one- or two-sided roof. It is about a house for temporary/provisional housing while the permanent house is constructed. Often a house from type *ramada* can be used in southern Zambézia as permanent house only constructed by neighbours for helpless old people.

Ramada, in the Cisena viewpoint, is by Denyer also called saddleback roof. (Denyer, 1978, pp. 138-139). One can see here the similarity with an *elephant's spine or "elephant's back"* -- ***nsana wa ndzou*** (See Table 6.2). With this comparison the researcher is not suggesting that the names or designations (saddleback and elephant's spine) influenced each other in their origin.

Nkope ya kolo, literally translated from Cisena means **monkey's face** and originates from the similarity between the front of this kind of houses and the head of hair of a monkey. The eyes correspond to the windows, the mouth correspond to the door and the hair, to the thatching.

Larson and Larson (1984, p. 100) divided the rectangular houses into two types: those *with* verandahs and those *without* verandahs, and explain that they (the houses) have always a hipped ridge roof.

6.4.2 *Nyumba ya mapara manai* — House of four-sided roof

The Echuwabu speaking house builders from Zambézia Province do not classify the houses with rectangular base according to different four-sided roof forms, whereas the Cisena speaking house builders distinguish three types of four-sided roofs, viz *nsukuli or ntsukuli, magóngwè* and *nhamagóngwè* (see table 6.2).

In this study the researcher will emphasize the description of the construction of roofs from *nsukuli* and *magongwe* types, indicating some elements of it's construction and the material used in the two Mozambican languages, namely Echuwabu and Cisena.

6.4.2.1 *Nyumba ya nsukuli* (Nyumba means house) -- House of *Nsukuli* type

This name designates houses in which roofs are cone shaped or squared right pyramid, that is, houses with circular or squared base. In this part one will speak about square based houses, then the circular based will be presented in a specific chapter -- Chapter 7. It is not clear why the roof of one square-based house, that therefore is a squared pyramid is named *nsukuli*, while *nsukuli* in Cisena means "top", a toy that in Mozambican tradition has the form of a cone. The researcher will try to answer this question in 7.1.5 of the thesis.

However, rectangular based houses in which the difference between width and length is not very big -- ratio between 1 and 1,4 -- can have roof with the form of a rectangular pyramid, but in this case takes the name of *nhamagongwe* in Cisena.

However, by the Bamileke, in Cameroon, one can find conical roofs (*nsukuli-shaped* roofs) sitting on square based houses. (Denyer, 1978, pp. 47-48).No further details about this were given in this study.

To construct a roof from type *nsukuli*, when the four main walls of the house are already erected, (i) *one determines the centre from the base of the house*, which lies in the intersection of two ropes stretched along the diagonals of the square base, on the ground, or (ii) *one determines the middle points of two opposite beams,* through folding a stretched rope in its middle point along each of the two beams. In each one of these two cases, (i) and (ii), one comes to a different form to construct a roof of type *nsukuli.*

(i) In the case in which one determines the centre of the base, one opens a hole at that place. Then one places in it a pillar with a length bigger than each of the posts of the walls, called *nzati* (Fig. 6.30), which will determine the upper vertices (apexes) from the pyramid of the roof. The length of the *nzati* depends on the inclination of the roof to be constructed.

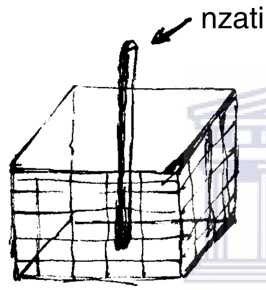


Fig. 6.30: nzati

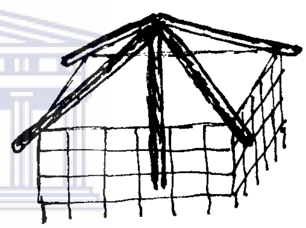


Fig. 6.31: Roof construction -- nzati with four phalupalu

At the top-end of the *nzati* four long sticks are tied or nailed to one another or to the *nzati.* These four sticks will pass through the four vertices formed by the main beams of the house (Fig. 6.31). These sticks are called *phalupalu* in Cisena and *mendo* in Echuwabu.

Next, other sticks are nailed or tied to the four former sticks (*mendo*) of the future roof, so that they become parallel to one another and perpendicular to the beam of the respective side (Fig. 6.32). These sticks take again the name *phalupalu* in Cisena and *paru-paru* in Echuwabu.

Finally more fine sticks are tied or nailed to the *phalupalu,* so that they become transverse to them and parallel to the beam of the respective side (Fig. 6.33). These fine sticks are placed in more or less equidistant rows, from top to the bottom. In Cisena they are called *mbalilo* and in Echuwabu, *balilo.* When this process is completed in all four faces of the roof, it is ready to receive the covering, after small finishing touches like cutting the extremities/ends of the phalupalu so that the new ends lie at the same distance from a particular beam, that in general is more than 30 cm outside the wall line.

After placing the covering, if the sticks from figure 6.31 were tied or nailed to one another and not to the *nzati*, the *nzati* can be removed, and the roof will look like a *vault* or *arched roof*.

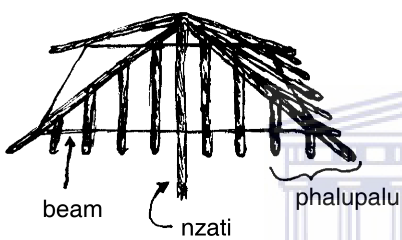


Fig. 6.32: roof with *phalupalu*

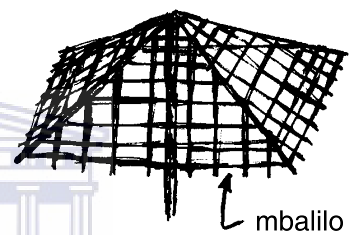
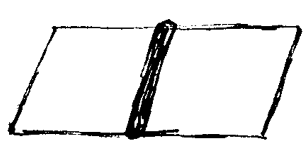


Fig. 6.33: Roof construction – *phalupalu* and mbalilo

(ii) For the construction of the other *nsukuli'*s variant, a thick stick is required that will be placed over two opposite beams, through their middle points (Fig. 6.34). This stick is called *ntanda* in Cisena. Over the middle point of this *ntanda* one places in vertical position another shorter stick on whose length the required inclination for the roof depends.

(iii) This last stick, that in Cisena is called *nzati* and in Echuwabu *mutana (*or *muamba),* can be fitted in a previously made hole in the middle point of the *ntanda* through a espiga made in the *nzati/mutana*, or through a forked cut made in the lower end of the short *nzati* (Fig. 6.35)



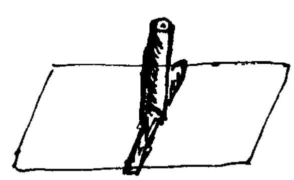


Fig. 6.34: roof construction — ntanda

Fig. 6.35: roof construction — ntanda with small nzati

Next, four sticks are tied or nailed to the *nzati* and each will pass through one of the vertices made by the main beams of the house (Fig. 6.36).

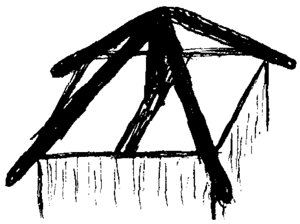


Fig. 6.36: roof of nsukuli type with phalupalu

The next process is similar to the one presented in **(i)** above with the only difference that in this case the *nzati* or *mutana* cannot be removed. The transverse stick, *ntanda*, can be reinforced with pillars which can later constitute a wall for a division of the house.

The name given in Echuwabu to one of the pieces of the roof, ***mutana****, reinforces and justifies the conviction presented in many interviews with house builders, that the roof is the most important and delicate part of a house. Thus the word mutana means* ***spine****.*

6.4.2.2 *Nyumba ya magóngwè* -- house of *magóngwè* type

The ***magóngwè*** type of roof is constructed for houses of rectangular base in which the measurements of the width (*w*) and the length (*l*) of the base are very different. In the studied cases the researcher found the ratio *l*:*w*≥1,4.

There are two different forms used for the construction of a roof of *magóngwè* type.

(i) The centre of the base, that is the point on the ground which lies in the intersection of two ropes stretched between opposite corners from the base of the house is dertermined.

Next, one determines the mid points of the widths of the base that is obtained by measuring from one extremity with a rope folded in half, which previously, before folding, corresponded to the measurement of the width. After that, a line is marked on the ground that links the mid points of the widths of the base that passes through the centre of the base.

Next, a small distance is measure on either side of the centre along the line linking the midpoints of the widths. The places are designate (a) and (b) as in figure 6.37. Holes are dug at the two places where pillars of the same height, but higher than the pillars measuring the height of the walls of the house, will be placed. The height of these two pillars will determine the height and consequently the inclination of the roof. These two pillars are also called *nzati*, like in the roof of *nsukuli* type.

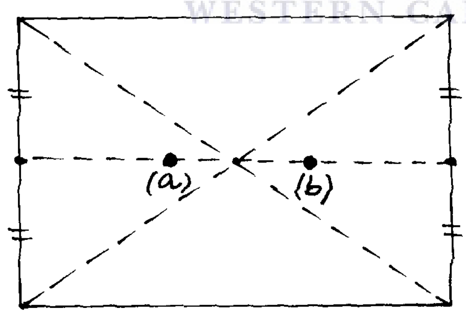


Fig. 6.37: preparation of roof of *magóngwè* type

On the top of these two *nzati* a transverse stick, called *ntanda*, is placed and in each extremity two long sticks are tied or nailed so that each of them passes through a corner formed with the main beams of the house (Fig. 6.38).

This, thus forms the main framework of a roof of *magóngwè* type.

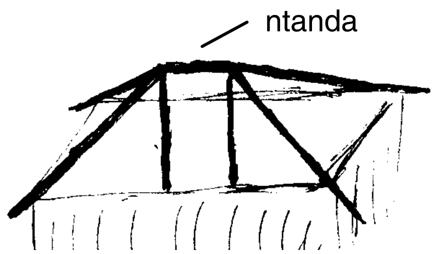


Fig. 6.38: *magóngwè* construction

To complete the construction of the roof's framework, sticks are tied or nailed to the previously placed four sticks (*phalupalu*) and to the *ntanda*, so that they become parallel to each other in each face of the future roof and at the same time perpendicular to the beam of the respective (or particular) face (Fig. 6.39).

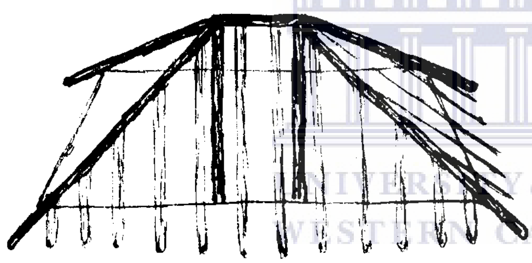


Fig. 6.39: phalupalu from *magóngwè* roof

Next, thinner sticks are tied or nailed to the *phalupalu*, so that they become parallel to each other and separated by a distance not bigger than 30 cm (often equal to a hand span), perpendicular to the *phalupalu* and parallel to the beams of the respective side. Like in the case of the roof of type *nsukuli,* these thin sticks have the name *mbalilo* or *balilo*, in Cisena or Echuwabu, respectively. After that, the roof is ready to be thatched. Sometimes there are some finishings on the roof that has as objective to go beyond covering defects in the roof edges that could facilitate their permeability to rain water (See Fig. 6.40 and compare with roofs in Fig. 6.28). This kind of finishing is used more in the south of Zambézia Province, where the covering is made with coconut leaves, generally woven together (called *nhoka* or *nyoka*). This is in contrast to the central and northern districts of Sofala Province where generally grass or straw are used for covering the roof. In fact, when *nhoka* is used to thatch a four-sided roof, it is not easy to thatch the roof edges very well. Thus, the house builder invented the brims in order to overcome this difficulty.

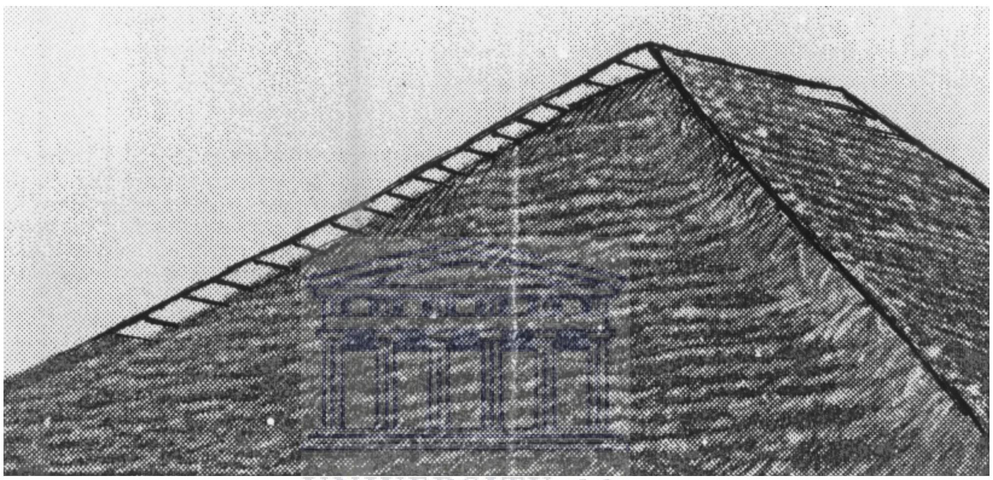


Fig. 6.40: Roof with brims anti-rain (brims still to be thatched)
Brandão Village, Quelimane (Zambézia Province)

(ii) Like a roof of nsukuli type, when a short *nzati* can start from *ntanda* and not from the ground (figures 6.34 and 6.35), in the roof of *magóngwè* type the two *nzati* can also start from the height of the main beams of the house. This is the most common method used by the house builders from Zambézia Province, at least in the studied area. For that, two parallel beams of equal length are placed perpendicular to the longer beams of the future house (Fig. 6.41)

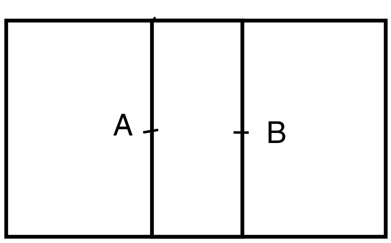


Fig. 6.41: beams to support two short *nzati*

Over the mid points of these new beams (A and B) two sticks, with a length corresponding to the desired height of the roof are fitted in. Over these two sticks (*nzati*s in Cisena, or *mutana*s in Echuwabu) another stick is placed (*ntanda* in Cisena and *batente* in Echuwabu), and the roof construction continues normally like from figure 6.38. The two new beams, the two short *mutana* and the *batente* have in Echuwabu the whole name *muamba.*

6.4.3 *Nyumba ya mapara meli* or *ramada* — house of two-sided roof

When the difference between the width and the length of the base is relatively big, it is not advisable to construct a roof of *magóngwè* type*,* because the central stick (*ntanda*) must be very long, and that could become ugly, in the opinion of the house builders. In these cases the roof must be two-sided, *ramada* in Cisena and called *mutompi wa mapara meli* meaning a roof with two faces -- (*mutompi* = roof) in Echuwabu.

The main characteristic of this type of roof that differentiates it from others, is that for this roof type the house builder has to decide before he starts where to place the wall's pillars, whereas for the other roof types the decision can be made even after the four main walls are ready. This difference can be justified through the fact that the walls related to the widths of the future house of *ramada* type must have in their middle points higher pillars, which will define the desired inclination for both faces of the roof.

The other pillars of the referred walls to have a gradual height difference, which defines the inclination of the roof (Fig. 6.42).

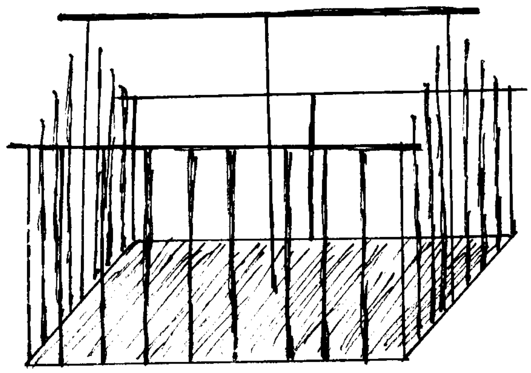


Fig. 6.42: The pilars and beams of *ramada*

The framework of the roof must exceed the wall's line in both roof faces, so that one can avoid that the walls, generally covered with mud, get wet through rain water. As a matter of fact, this is applicable to any roof type.

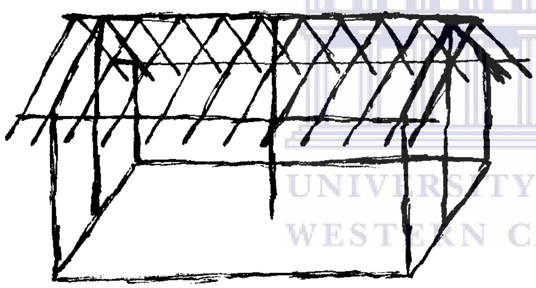


Fig. 6.43: beams and phalupalu of *ramada*

Larson and Larson (1984, pp. 114-117) present three methods for roof support. These authors do not indicate the name of each roof type for houses with circular base and with rectangular base. But in terms of shape it can be said that the Tswanas use roofs of type *nsukuli* for houses with circular base and of type *magóngwè* for houses with rectangular base, though the construction methods are different from those used in Mozambique, more particularly in Sofala and Zambézia Provinces.

In other daily life activities other structures can also be found which are similar to square based pyramid (*nsukuli*) and to *magóngwè* roofs. For example the orange sellers in Mozambique have their own forms of displaying their oranges, so that they can make a good impression on the buyer about the quantities of oranges in each heap. Amongst the many forms, two are of interest (Fig. 6.44)

Square base (*nsukuli*) Rectangular base (*góngwè*)

Fig. 6.44: Heaps of oranges
Adapted from Lopes et al (1990, p. 60)

6.4.4 Inclination of the roofs of houses with rectangular base

Here a description shall be given about the angles formed between the horizontal plane and the faces of the different roof types of houses with rectangular/square base. These angles define the inclination of the faces of the roof that determines the speed with which the rain water falls from roof.

6.4.4.1 Inclination of a roof of *nsukuli* type

Through observations and measurement a conclusion is drawn that the four faces of a roof of type *nsukuli,* which are triangular, have the same inclination in a house (one avoids here to speak about *tangents*).

This inclination is smaller at sea level, both in Zambézia and Sofala Provinces, where one finds savannah areas in plain land, and bigger inclination in the inland, where one can find greater forest density and more or less mountainous highlands in Sofala Province. The correspondent angle of inclination in roofs of nsukuli type in plain land varies between 30° and 45° (Zeca's house and Mrs Madalena's house, respectively, in Maquival, Zambézia Province). Without concrete examples, Frobenius reported the same observation by Bantu people of central Africa -- "*Diese haben vielfach höhere Dächer als diejenigen der Küstenvölker, ...".* (Free translation: "These have generally higher roofs than those from the seaboard peoples, ...".) (Frobenius, 1894, p. 45).

6.4.4.2 Inclination of a roof of *nhamagóngwè* type

This roof type has equal opposite faces. The four faces are triangular and two of them have bigger bases than the other two. The triangles with smaller bases have a lesser stressed inclination than the inclination of the other two.

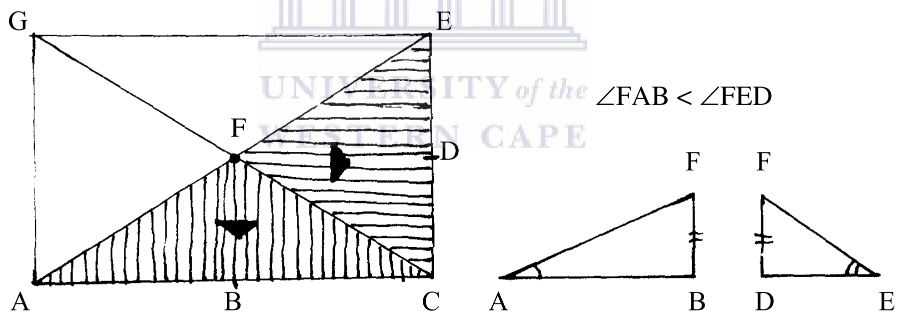


Fig. 6.45: Inclination of roof nhamagóngwè

In the picture, α (= ∠FAB) is the angle between the horizontal plane and the face CEF or AGF of the roof and β (= ∠FED) is the angle between the horizontal plane and the faces ACF and EGF. The measurements of these angles vary as follows: $25° \leq \alpha < \beta \leq 50°$.

6.4.4.3 Inclination of a roof of magóngwè or *góngwè* type

The construction of this roof type has the main objective of removing the inclination differences between the roof faces. So, all four faces of a roof of *góngwè* type have nearly the same inclination related to the horizontal plan. The angle of inclination varies between 30° and 45°.

This type of roof has equal opposite faces, being two triangular and two isosceles trapezia.

6.4.4.4 Inclination of a roof of ramada type

As described previously, the roof of *ramada* type is composed of two rectangular faces. Generally the two faces have the same angle of inclination in relation to the horizontal plane. However, there are house builders who construct one of the faces more inclined than the other one. *Generally, the more inclined face is built on the side from where the heavy rain comes and, consequently, the wall of this side is lower than the opposite one. Physically seen, a bigger inclination of the roof face increases the speed with which the rain water falls from the roof, avoiding the infiltration of water into the house's interior. Once again, there is no scientific evidence that the house builder who invented this roof variant was explicitly thinking scientifically.*

Given the reduced number of houses observed with this kind of roof, the researcher prefers not to indicate the limits of the angles of inclination.

The house builders think that the roof of *ramada* type must be constructed in regions where one knows very well from which side or direction the strong winds come. For, when a strong wind comes from the side of the house where there is no roof face, the roof can be lifted and destroyed through the wind's power.

For any roof, a bigger inclination means bigger speed with which the rain water falls from the roof, but it can also mean more construction materials and also bigger area exposed to the wind, which has a negative impact. On the savannah, near the coast (Zambézia and Sofala), where the roof can easily become dry after the rainfall, the roof inclinations are less emphasized. In the inland (Sofala Province), where the sunrays penetrate with difficulty and at the same time it rains often, the roofs have a bigger inclination.

In other parts of Africa, Bantu traditional house builders also thought like that about roof inclinations, and this way of thinking is not a recent phenomenon. (cf. Frobenius, 1894, p. 29-49)

The next chapter, chapter 7, presents data on construction of houses with circular base and some data of both circular and rectangular based houses.

7. Data and data analysis on houses of circular base or round houses and some data that relate circular with rectangular based houses

This chapter consists of the description, on the basis of observation, statements and stories of the building/construction process of a house with circular base by people with no (or little) schooling. It also covers analysis of the underlying geometry and geometrical thinking, as well as some geometrical concepts used, preferably in local language and their literal translation into English. In this chapter also some data that relate rectangular with round houses will be presented.

Unless indicated otherwise, all data presented in this chapter result from the researchers field work.

7.1. The building process of houses with circular base

For this study many observations and conversations were made with three house builders, viz., Chico Samo (42 years old), António (40 years old) and João Manuel (27 years old) in September 2002 -- see interview Sofala-6, in Appendix A.

7.1.1 Circle construction

After the selection and preparation of the ground the house builder constructs the circle, the base of the future house.During the collection of the data by the house builders we found only one method of circle construction.

This method coincides with the one found in the literature by INDE (1984b, p. 79). For the construction of a circle the house builder needs two short sticks and a long rope. He pins one of the sticks to the ground and ties the ends of the rope together making a kind of ring. He lays the rope down on the ground so that the 1st stick (A) stays on the ring (Fig. 7.1). Next, he takes the 2nd stick and puts it in the ring stretching the ring made by the rope.

With the rope so stretched the house builder marks on the ground with the 2nd stick (B) around the 1st stick (A) until returning to the starting position (Fig. 7.1). So, the figure obtained on the ground is a circle, which will determine the circular base of the house. This method is commonly known, at least in Mozambique, as the gardener method. The researcher also knows the gardener's method to construct an ellipse, but it will not be described in the thesis, because the researcher did not meet house builders who use this method. This method of circle construction is also similar to the one described by Larson and Larson (1984, p. 111) where the sticks or pegs are substituted for nails and the rope for string.

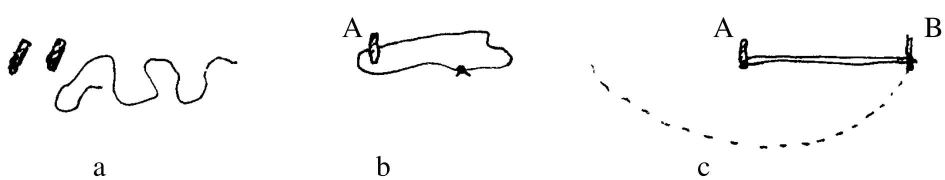


Fig. 7.1: Circle construction

This procedure is the more direct application of the definition for a circle used in Mozambique and is more understandable for the beginners studying geometry, than the use of a pair of compasses.

The most common definition of a circle is that ***it is the entire union of points in the plane which lie at the same distance from given point, called the centre****. This "same distance" or "equal distance" is in this case materialized by* *the rope, which is not an elastic band, whereas with the pair of compasses one has to imagine the so-called "same distance" or "equal distance". This same observation can be applied to the definition according to which a circle is* **"a plane curve that is the locus of a point which moves at a fixed distance (the radius r) from a fixed point (the centre)"** (Dainitith and Nelson (ed), 1989, p. 54). How to "see" easily this "fixed distance" when a pair of compasses is used? -- *asks the researcher.*

7.1.2 Placing the posts

After the construction of the circular base the house builder marks the spots where holes with the necessary depth should be made for the posts. The stick (A) (Fig. 7.1) cannot be removed yet from the centre. Then the first post is placed in its hole and the house builder examines if the post has the desired height for the future house. If not, then the post is removed from the hole and another post with a different length is placed in its place. After a post with the desired height for the house is found, it is removed from the hole and other posts are prepared or cut using this one as gauge. Sometimes this test of the height is made using a stick without any special utility. To verify the verticality of the post the house builder uses one of the two methods described in 6.2.1a and 6.2.1b of the thesis. The only difference is that in the case of houses with circular base one can start with any post, given that there are no corners. After the first post is well placed and fixed in its hole, the remaining posts are placed.

Next, one passes a rope over the tops of all posts. With the help of this rope or a thread the house builder can examine if all posts have the same height, given that one hole can be more or less as deep as the others or the ground may not be completely level. The posts are fixed in their holes when the house builder is sure that all posts are at the same height.

Generally, for houses of circular base posts from type a) and b) described in 6.2.2 of this study, i.e., *posts made of a small, not very smooth tree trunk or branch* or *posts made of bamboo* are used. The distance between posts is determined by intuition and it is bigger where doors will be placed.

7.1.3 Placing the beam(s)

The beam for this type of house is a very long tree branch or pole or green bamboo that can be bent and curved into a circular format. Depending on the size of the house one can join tree branches or green bamboos through a rope to constitute the beam. To avoid that the top of the cylindrical wall would not be circular, while one places the beam, the house builder places it after he has guaranteed that the circle of the top will not be exposed to a deviation. For that the house builder constructs two circular rings *(kassa, pl: makassa)* with tied green poles, one ring inside the posts and the other one outside the posts, both on the ground, close to the bases of the posts (Fig. 7.2) -- rings A and B, respectively.

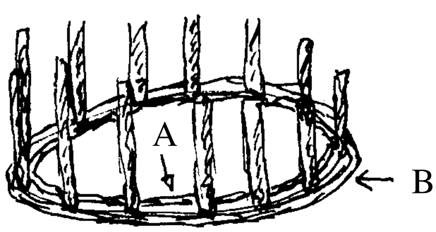


Fig. 7.2: Circular rings A and B *(makassa)*

These two rings are then transferred to near the top of the posts and tied to all posts at the same height. So, both the base and the top of the future wall have a circular form.

Only after the placement of the *makassa* near the top of the posts is the beam placed on the top of the posts in slits with v-form *(mpanda)*, or fork, existing on the top of the vertical posts. The house builder places the posts so that the slits are in a position favourable to the placement of the beam.

This procedure shows us that the house builder is conscious that the holes in the ground, into which the posts are fixed guarantee that the circular base remains stable, whereas the circle on the top of the cylindrical wall can be pushed out of shape by forcing the beam to become circular. Because of that, it is necessary to stabilize the top through two rings constructed at the base of the future house and then transfer to the highest point of the posts, that makes clear the idea that the vertical translation in the space is an isometric transformation -- he transfers the makassa *made on the ground to the highest point of the posts so that the circle determined by the posts on the ground and the one to be formed by the beam on the top of the posts become equal. This procedure demonstrates that the house builder is seriously interested to obtain a cylindrical/circular wall.*

7.1.4 Construction of the walls

After the placement of the beam more rings *(makassa)* are tied on the outside, from top to bottom, separated at a distance of nearly a hand span. (Fig. 7.3). Drums, tables, mortars and already placed battens can be used as scaffolding in traditional house building.

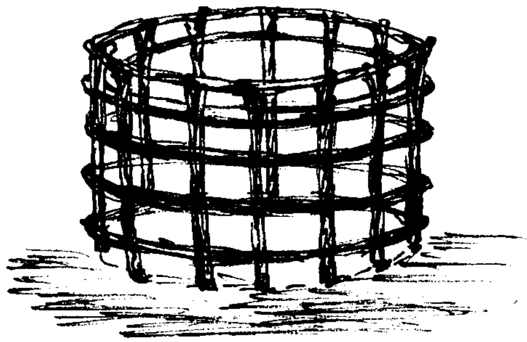


Fig. 7.3: Cylindrical wall with external *makassa*.

After this step one can construct the roof or it can be constructed when the wall is ready. We shall describe the case in which one first completes the construction of the wall frame. That is different from the method used in Botswana, where the wall of a traditional house is built of mud only. (Larson and Larson, 1984, p. 13). After placing all external *makassa* the house builder begins to tie some sticks or reed on the inside of the wall in the vertical position, always inverting the sticks or reed bundles, some with the thin part facing the top and others with the thin part facing the bottom, so that each space of the future wall between two posts becomes very well filled. These sticks or reeds have in Cisena the name *ntchintchi*.

During this process a space between two posts is not filled, where a door will be placed. The windows, as required, will be placed later. Generally, houses of circular base, in Sofala Province, have no windows and have only one door. The door can be made of wood or can be simple made with reed. On the contrary, in Botswana only about one quarter of the circular houses have no windows, while the other ones have one or two windows (Larson and Larson, 1984, p. 98). This difference can be attributed to the differences in the climates of the respective countries, Mozambique and Botswana, even if both are tropical African countries.

Next, the internal *makassa* is tied on, each corresponding to one *kassa* tied on the outside of the wall. The *makassa,* both internal and external, will help to secure the mud, which will be used to cover the wall. Generally one covers the wall with mud by hand first from inside and leaves the mud dry lightly for a few of days. This is done after placing the door, if it is made of wood. Afterwards one covers the wall on the outside with mud and leaves also to dry lightly. Finally, one covers the wall with mud on the inside and on the outside with the last layer and then smoothes it *(kunzira)* by hand while the mud is still moist/humid.

In Cisena the process of covering the wall with mud is called *kunama.*

Generally the tasks of *kunama* and *kunzira* are reserved for women and children. Another task reserved for women and children is paving the floor of the house, generally made of black mud called *chikowa*, which becomes very hard when dry.

The traditional house building in Botswana generally uses no sticks for the walls. One uses only sand bricks, wet or sun-dried and mud. (Larson and Larson, 1984). In most of the countries "... in at least the rural area of tropical Africa ... thatching was often done by women ...". (Denyer, 1978, p. 92).This is also the case even in Mozambique, but not in the areas of this research.

7.1.5 Construction of the roof of *nsukuli* type

Houses of circular base, also called round houses have only one type of roof which is conical shaped. The house builders from Sofala Province name this type of roof a *nsukuli* or *ntsukuli,* as presented in section 6.4.1, Table 6.2 of the thesis. For the construction of the roof from type *nsukuli* on houses with circular base one removes the stick (A) from the centre of the base (Fig. 7.1) and opens a hole

on its place, where a pillar higher than the posts of the wall will be placed. This pillar is called a *nzati*, and will serve as a support for the higher point of the roof to be constructed. At a certain height of the *nzati* one ties a rope and stretches it to the beam. One changes the position of the rope on the *nzati* until the house builder finds the advisable inclination for the future roof. So, one cuts the *nzati* with the necessary height and fixes it well in its hole. With the rope stretched from *nzati* to the beam of the house one has the idea of the length of the sticks of the roof frame which will go from the *nzati* to the beam and named the *phalupalu*, in Cisena.
The construction of the roof begins outside of the future house and ends on the top of the cylindrical wall, its definitive position.

After placing the *nzati* one cuts four long sticks with a length bigger than necessary for *phalupalu*. One makes a furrow near the thick end of each of the future *phalupalu* (Fig. 7.4).

Fig. 7.4: *phalupalu* with furrow.

Next, the four sticks are tied to one another with a rope which passes through the furrows. Afterwards the thin ends are separated so that the all entire unit is up on the ground supported by these four extremities (Fig. 7.5).

Next, this position, in which the four points on the ground determine nearly a square, is lightly stabilized through two small rings (*makassa*) one internally and the other one externally tied, near the top of the *phalupalu* (Fig. 7.6).

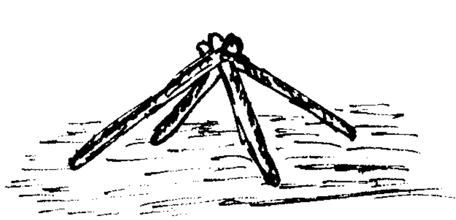


Fig. 7.5: The four *phalupalu* joint through a rope

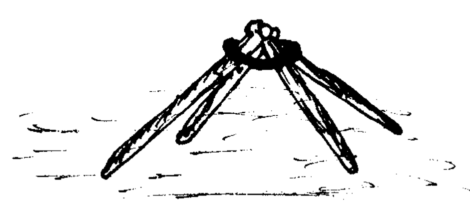


Fig. 7.6: *Phalupalu* with one external *kassa* (batten)

After that, the structure is taken and placed on the top of the circular beam of the (future) house, in such a position that the centre of the structure fits on the top -- apex -- of the *nzati* (Fig. 7.7)

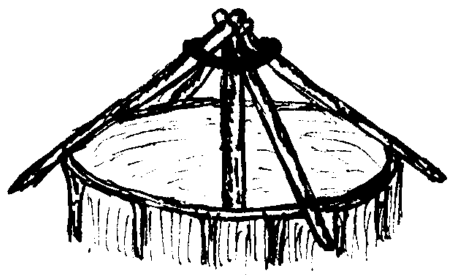


Fig. 7.7: Roof structure with *nzati*.

Maybe the fact that the roof for a house with square base and that for a house with circular base begin with four phalupalu, they take the same name **nsukuli.** *So, the right squared pyramid is incorporated in the (circular) cone. Therefore, the cone appears as a result of the rotation of a pyramid around an axis, in this case around the* nzati. *The* nzati *is the revolving axis.*

The next step is to tie or to nail more *phalupalu* in the spaces between each two of the four first phalupalu and tie more *makassa* from top to bottom. Generally the remaining battens -- *makassa*-- are only tied externally. Next the *phalupalu* are cut by a bushknife or sawed, so that they all have the same length. After that, the *nzati* can be cut and removed, or it can be kept. In any case, the roof is ready to be thatched. Roof of this type has an inclination that can reach the angle of 60°.

Roofs of *nsukuli* type for houses with circular base are thatched with straw of the types *khatase* and *nsengansenga* (names in Cisena).

The process of thatching the roof begins from bottom to the top. The straw, woven or not, is tied to the second *kassa* (Fig. 7.8). Next, the process of thatching continues changing to the third *kassa* (Fig. 7.9) and so on, until one reaches the top of the roof.

Fig. 7.8: The thatching of the roof begins on the second *kassa*
(Drawing by the researcher, adapted from INDE, 1984b, p. 39).

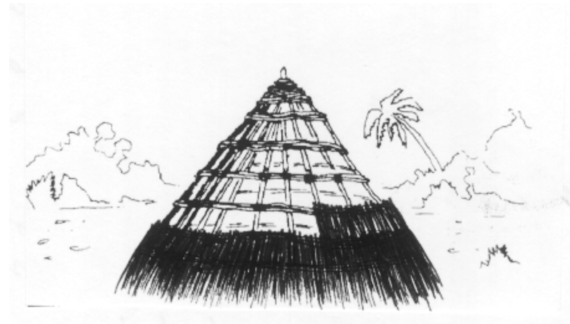


Fig. 7.9: Second thatching line on the roof nsukuli (third kassa).
(Drawing by the researcher, adapted from INDE, 1984b, p. 39).

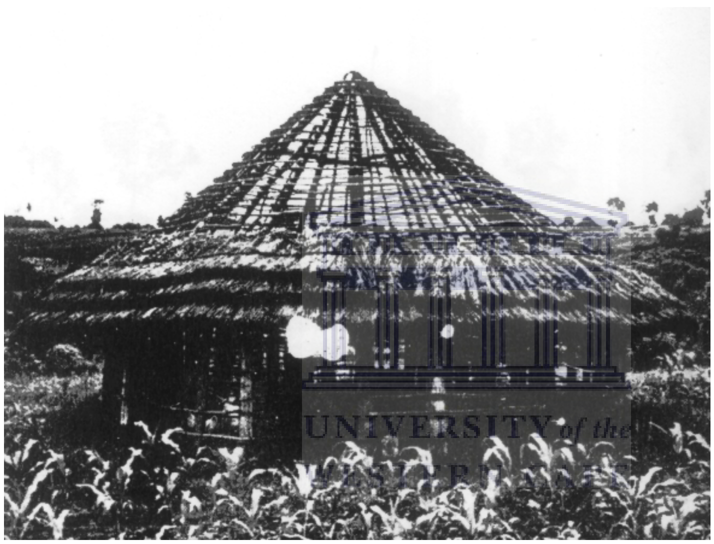


Fig. 7.10: Third thatching line on the roof nsukuli.
In Andersen (1977, p. 156), layered thatching method.

After thatching the roof the house builder cuts the straw that exceeds the wall line, always so that rain cannot wet the wall.

In order to reach a good stability for the straw, so that it cannot be lifted with the wind, one ties a *kassa* over the straw near the bottom edge of the roof. This is contrary to what happens, in Botswana, using the traditional thatching method,

> when all grass is in place, it is fixed to the roof by tree bark strings running from one side of the house over the grass to the other and forming a

network. The strings are tied only to the battens at the bottom of the roof structure (Larson and Larson, 1984, p. 118).

So, that it couldn't be blown away by the wind, given that the grass is simply spread out on top of the structure of the battens. The two thatching methods used in Botswana are the *traditional thatching* and *boer thatching*. (Larson and Larson, 1984, p. 120).

The above described Tswana thatching method, forming a network of strings over the thatch, as only seldom found in districts of Caia, Cheringoma, Gorongosa and Nhamatanda – in Sofala Province – in roofs of round houses. An exception is the roof of *góngwè* type in figure 6.29, in Chapter 6.

The *boer thatching* method, so called by Larson and Larson, is recently entering in some Mozambican beach zones, including Sofala's beaches. By this thatching method Mozambicans are used as mere labours thatching bungalows with imported straw in tourist ranches, some of them pertaining to South African economical investors.

7.1.6 The divisions of a house of circular base

In this section the divisions in houses of circular base among the *Sena* of Sofala Province are presented. The houses with a single circular wall have generally only one, two or three divisions (Fig. 7.11 and Fig. 7.12).

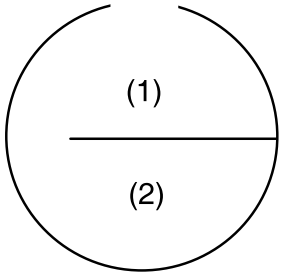


Fig. 7.11: House with 2 divisions
(1) living room;
(2) bedroom

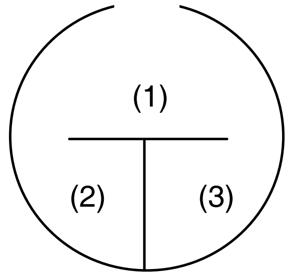


Fig. 7.12: House with 3 divisions
(1) living room and larder
(2) children's bedroom
(3) parents' bedroom

(Formally, larder is a small room used for storing food and other things.)

Houses with a double circular wall have in general more than three divisions (Fig. 7.13). The circles, which determine the bases of both walls have the same centre and the first to be constructed is the internal one, therefore the one with the smaller radius.

The house builder from Marutse Kingdom also began with the construction of the internal circle. (Frobenius, 1894, pp. 19-21). Larson and Larson also describe a special type of Tswana circular house, the *double walled* house where "part of the wide verandah is enclosed by a wall". (Larson and Larson, 1984, p. 98)

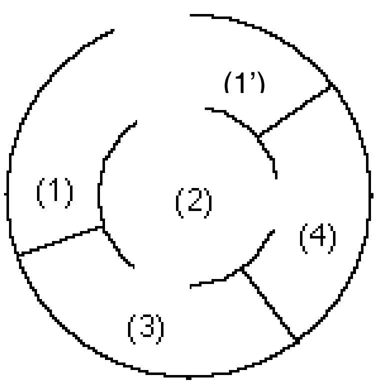


Fig. 7.13: House with two circular walls
(1) and (1') living room and larder
(2) several furniture and other utensils
(3) bedroom 1
(4) bedroom 2

7.2 Classification of traditional houses according to the type of basis -- circular and rectangular

With regards to the type of base, the house builders from Southern Zambézia have no specific classification, given that they hardly ever construct houses with no rectangular base. However, a house was found in Quelimane with octogonal base, but it was located such that the researcher couldn't take any photograph and unfortunately couldn't meet the builder. Meanwhile, among the Cisena speaking house builders from Sofala Province the researcher found six house classifications as shown on the Table 7.1, below.

Table 7.1: Classification of traditional houses according to base type and size and/or usage

Classification	**Bases type**	**Observations**
1. *Kumbi* or ***alidondo***	Circular	Normal or over size
2. *Tsecule*	Rectangular	Normal or over size
3. *Guero*	Circular with reduced dimensions	Small sleeping house for adolescents or old men/women
4. *Yapontaponta*	Squared	Normal or over size
5. *Mutini* or ***Ntine***	Circular	Small sleeping house with semi-spherical or conical form for adolescents or old men/women
6. *Chete* or ***tsete***	Circular or squared	Small house made over a squared or rectangular stand.

Note that figures in the Table 7.1 would not illuminate the classification, given that size and usage cannot be easily illustrated by drawings or photos.

Mutini or ***Ntine*** is a very small circular based house, only for sleeping, without windows, that has the form of a semi-sphere or cone. In the case of a *mutini* it is not easy to make a distinction between the wall and the roof (Fig. 7.14).

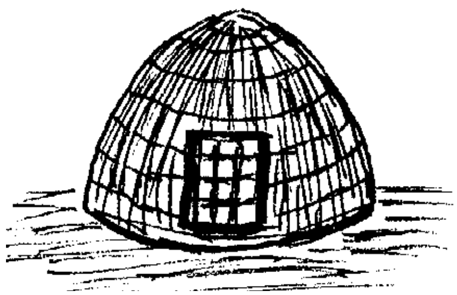


Fig. 7.14: *Mutini* or *Ntine*

Frobenius (1894, p. 11) also writes about “wall-less” or “wall-free” houses (*wandlosen*, in German), i.e., houses in which the roof cannot be distinguished from the walls, or even, houses without walls. Moriarty (1980) found this house type too, in Tanzania, and named *traditional “hemispherical-shaped hut of grass and poles, with no clear distinction between walls and roof”*. (1980, p. 287).

Chete or ***tsete*** is a kind of house (circular or square based) made over a squared or rectangular platform or stand. Usually it is used as granary for cereals or as chicken rum. (Fig. 7.15).

Fig. 7.15: *Chete* or *tsete*

In Medeiros(ed.) (1993, cover)

There exists a 3^{rd} classification of constructions according to the usage only, independent of base type and roof type.

<u>Classification by usage only</u>, in Cisena:

1. *Nsanza* or *ntsapi*— granary;
2. *Thanga* — housing for cattle, pigs and kids;
3. *Mbhala* or *mphala* — hen-house;
4. *Ntsaka* — small shed;
5. *Matchessa* — big shed

<u>Classification by usage only</u>, in Echuwabu:

a. *Ndara* — granary;

b. *Thanga* — housing for cattle, pigs and kids;

c. *Kapwere* — hen-house or chicken rum;

d. *Muthengo* — shed;

e. *kasa di banho* - bathroom (outside the house).

Bathroom in Echuwabu is similar to the name in Portuguese, viz., **casa de banho**.

7.3 Some data from media

One of the objectives of the house builders is to construct cheap and lasting traditional houses. According to Benessene, a mozambican meteorologist, our country lies in an Inter-tropical Convergence Zone (ITCZ). “The ITCZ is a band of migratory clouds around the globe, where the Trade Winds of both hemispheres meet...” (Benessene, 2002, p. 11). The ITCZ directly influences Mozambique’s rainfall system mainly to the north of the Save River (cf. Benessene, 2002, pp. 9-21) that includes the whole region covered by the present study on traditional house building.

From media we could also collect some data related to house building in Mozambique. From media, between Dezember 2002 and March 2003, we had opposite experiences about the hard-wearing of traditional built houses in two different Mozambican regions. In northern Mozambique, in Nampula Province, the cyclone “Delfina” (31^{st}.12.02 - 05^{th}.01.03) caused the destruction of many traditional houses, whereas in central Mozambique, in northern Inhambane and southern Sofala -- by Save River -- traditional built houses resisted the cyclone “Japhet” (March.2003) even in water (see figures 7.16 and 7.17).

It may be clear that one cannot make a purely scientifical comparison, because one didn’t have the dwelling density of each region, the severity of each phenomenon (cyclones), the nature of the soils, etc. But this situation incorporates a preoccupation that may need an interdisciplinary research.

Fig. 7.16: Machanga (Sofala) and Mambone (Inhambane). DM-newspaper, March 12, 2003

Fig. 7.17: Machanga (Sofala) and Mambone (Inhambane). DM-newspaper, March 12, 2003

This preoccupation increases when the fact that Mozambique is very vulnerable to natural disasters such as *tropical cyclones* and *periodical floods* is taken into account.

In chapter 8, the next one, the researcher will try to put together the mathematics that one believes to be involved in traditional house building in Sofala and Zambézia Provinces, among the Sena and Chuwabu people, respectively. In the same chapter the researcher will also demonstrate the correctness of some algorithms used by the house builders, for example, to construct the rectangle.

8. What mathematics is involved in the traditional house building in Zambézia and Sofala Provinces? A general data analysis

In this chapter the researcher will bring together the relevant mathematical elements found in the traditional house building, both rectangular and circular in Sofala and Zambézia Provinces. He will also try to demonstrate the correctness of some algorithms used by the house builders, for example, to construct the rectangle.

To recognize the hidden geometrical thinking and knowledge in the traditional house building the researcher will employ the method inspired by Gerdes:

> In our analysis of the geometrical forms of traditional -- Mozambican -- objects, like baskets, mats, pots, houses, fish traps, etc., we posed the question: *why* do these material products possess the forms they have? In order to answer this question, we learned the usual production techniques and tried to varying the forms. (Gerdes, 1995a, p. 28).

Given the lack of of time and of lack of building material the researcher *didn't try to vary the forms in the practice,* but *he learned* enough of *the usual production techniques.* So he has the conviction that, at least theoretically, he is prepared to analyze the data on traditional house building, i.e., to ask the question *why*?

In this chapter not all the data will be analyzed, given that:

(1) some of the data was discussed already in chapters 6 and 7;

(2) more information will be given in chapter 9, where a discussion on how one can incorporate the mathematics (especial geometry) found in the traditional house building -- in Sofala and Zambézia -- in mathematics teacher

education in Mozambique will be done.

Questions in some sections of this chapter may not be seen as tasks to be solved, but as questions to help the readers to follow the researcher's reflections and analyses around data on house building.

8.1 Basic terms for Elementary Geometry

In this section the researcher presents some basic terms for elementary geometry in Echuwabu and in Cisena with the respective meanings in English. These terms where collected from interviews and conversations with house builders.

Table 8.1: Basic terms for elementary geometry in Echuwabu and Cisena

Geometrical term	**Words in Cisena**	**Translation into English**	**Word in Echuwabu**	**Translation into English**
angle	wakulungama; nghomu	funneled; corner	komo (1)	corner
vertical	(wa)lungama	standing up	(yo)wimela dereto *	(to be) well standing up
horizontal	(wa)guangwa-nyka **; tambalala	lying down over two equal high supports; lying down	(y)oguagua-nyea *; sawe-sawe	lying down over two equal high supports; lying down
oblique	(wa)pendama **	tilt	yotedemana*; yovedhama *	leaning

Table 8.1: <u>(continuation-1)</u>

Geometrical term	**In Cisena**	**Translation into English**	**In Echuwabu**	**Tanslation into English**
ranged (or **in a line)**	(wa)lungama; ndendende	ranged	(o)nyaalia, otherula ***; yonyala; yowalinharea * (2);	straightened out; forming a straight line
middle	pakati na pakati	in the middle point of a line, even curved one *(at equal distance from the ends)*	vari-vari	in the middle point of a line, even curved one *(at equal distance from the ends)*
center	pa nzati; pakati; guta	in the middle, coming from different directions	vari	in the middle, coming from different directions
vertex	nghomo	corner	tompa	tip
corner	nghomu	corner	komo	(inside) corner
curved	khona; gongonyoka	crooked	(yo)apela *; okoromana	curved; to be crooked
circle	___________	___________	(ya)rodondo *(3)	round

Table 8.1: (continuation-2)

Geometrical term	In Cisena	Translation into English	In Echuwabu	Translation into English
Triangle	fondri	funnel	nga matuwa*; nakomoni tharu (5)	like traditional hearth or cooker *(three stones)*
rectangle	nhamagóngwè	olive oil can(4) block's face	ya elapi *	of length (4)
square	yapontaponta* nyakhomukho mu	equal long (6); with corners	komo dh'oli-gana	equal corners
straight	dzongoka*; wakuzongoca*	straightened	(o)ogola; onyaala	straightened; to be straight
diagonal	ntsana (6); uguanguanyi	spine; from a corner to the other corner	komo na komo; muguaguanyo	from a corner to the other corner (not con-secutive corners)
rotation	zungumisa; zungunuka	inversion or turn round	ozugunuwa	inversion or turn round
translation	fendeza; sussa; fulussa	transfer; to remove	otukuma; ofedhia	to push; to remove
half	mentade; hafo	from half in portuguese: *metade*; and from english: *half*	meia	from half in portuguese: *meio/meia*
short	vyra (7)	short, low	(ya) okiva (8)	short, low
long	alhapa (7)	long, high, tall	(ya) olapa (8)	long, high, tall

Table 8.1: <u>(continuation-3)</u>

Geometrical term	Into Cisena	Translation into English	In Echuwabu	Translation into English
Low	vyra (7)	low, short	(ya) okiva (8)	low, short
high, tall	alapha (7)	high, tall, long	(ya) olapa (8)	high, tall, long
small	ingono	Small	engono	small
big, large	ikhulu	big, large	endimuwa	big, large
pyramid	ntsukuli-góngwè	From pyramidal roof	--------------	----------------
cone	Ya n'guli	top-shaped	n'guilli	top (a toy)
rectangular prism	nhamagóngwè (9)	like an olive oil can	n'ga ntuwa * n'ga sizora *	like a brick

Notes on Table 8.1:

(1) The Echuwabu speaking house builder knows only angles smaller than 180°.

(2) From portuguese, *alinhado* (= yow**alinhar**ea)

(3) Depending on the context, (ya)*rodondo* can also mean *spherical.* Look to the similarity between (ya)***r****o***dondo** and ***r****e***dondo**, from portuguese.

(4) Only understandable as rectangle in the context.

(5) *Nakomoni tharu* means *that has three corners (*or *three angles)*.

(6) Only understandable as diagonal in the context.

(7) Only in context can one differentiate "vyra" for *short* and *low*; and "alapha" for *tall/high* and *long*, in Cisena.

(8) Only in context can one differentiate "okiva" for *short* and *low*; and "olapa" for *tall/high* and *long*, in Echuwabu.

(9) Often used for roof type, meaning rectangular pyramid.

*   These terms are not used in abstract situations. There are used in connection to something.

**   These terms are not used in abstract situations. The prefix (wa) is for singular and (ya) for plural.

*** The term *otherula* means straighten out but, it is only used for rigid materials, like tree branches, sticks, etc.

In Echuwabu and Cisena many geometrical terms are used as adjectives and not as nouns, or there are verbs, like *translate* (*fulussa* = to [re]move) (See table 8.1.). For example, in Cisena, *vertical* doesn't exist but, something can be vertical (*walungama*). At this point one could ask again the question by Gerdes: "Where do (early) geometrical ideas come from?" (Gerdes, 1995a, p. 29). -- One short answer to this question could be that they come from human interaction with the reality, *from human activities*.

In Echuwabu there is a term for *horizontal (oguaguanyea)* but one uses more the adjective -- *yoguaguanyea*. (See table 8.1).

In Cisena the adjectives have the prefix **wa** for singular form and **ya** for the plural form, whereas in Echuwabu one uses **ya**, **yo**, **wa** and **wo** for the singular form and **o**, **a**, **dha** and **dho** for the plural form. But the prefix "**o**" can also appear as an indicative for verbs, like *onyaalia* -- to straighten out -- or as prefix for gender and number neutral adjectives. There are more geometrical terms in Echuwabu like, *ekivi* (= shortness), meaning width; *elapi,* meaning length or height or even "tallness".

8.2 Formation of new concepts (some examples)

In the formation of geometrical concepts the researcher came across, among other situations, the use of the same word or expression for daily life objects and for geometrical shapes or concepts and association of names. This phenomenon is not new in mathematics. For example, in every language words for numbers are coined freely in several ways, the same word can be used for a number and a body part or an object. The following passage by Ascher and Ascher can be used as an illustration for that: “For example, when an English speaker says ‘a foot’ in the context of measurement, no English hearer thinks he is thinking of a body part.” (Ascher and Ascher, 1997, p. 27).

The researcher agrees with Borba when he writes that “just giving something a name shows the importance this thing has in a given culture”. (Borba, 1997, p. 263). So, one can say that geometrical concepts and forms are of importance in traditional house building.

Now the researcher will present some examples both in *Cisena* and in *Echuwabu*.

* *fondri* — is the name given to triangle in Cisena. This word is used also for *funnel.* According to the informants, the first funnels where made of folded leafs and used for putting water into special transport and drinking pots with slim (bottle)necks. These funnels had a triangular longitudinal section.

* *nga matuwa* or *n'ga matuwa* — is one of the two designations given to triangle in Echuwabu. This expression means “like a cooker”. In fact the traditional cooker or hearth is composed of three stones, which reminds one of the three vertices of the triangle.

* *na****komo***ni tharu* — is the other designation for triangle in Echuwabu, that means “that has (or with) three corners” or “that has three angles” -- from *komo = corner or angle* and *tharu = three*.

* *n'ga ntuwa* — is the designation given to a rectangular prism. *N'ga ntuwa* means “like a brick”, in Echuwabu.

* *ya n'guli*, in Cisena and *n'guilli*, in Echuwabu — are the names or expressions

given to cone. *Ya n'guli* means "with a form of a n'guli", that at his time means top -- a toy with a form of a cone -- and *nguilli* means also top, in Echuwabu.

Other situations mentioned above can be, for example, the fact that one word can have several meanings in geometrical context. For example, the word *vyra* in Cisena can mean *short* or *low*; the word *alapha* in Cisena can mean *high*, *tall*, or *long*; and *endimuwa* in Echuwabu can mean *big* or *large*. The meaning of these words one can understand only in context. For this one finds the following reflection by Borba: "Meanings of signs also change from one cultural group to another, since each group 'shapes' the meaning of words to their context." (Borba, 1997, p. 263)

8.3 Geometry of the traditional house building related to the geometry of the grades 1 to 3

In this section the researcher shall present parts of traditionally built houses as static examples both for the planar and for three dimensional geometry for the school grades 1, 2 and 3. The objectives of the geometry curriculum in these grades were presented in Chapter 2, section 2.2.

- using bases of traditional houses the teacher can ask the school pupils to identify a rectangle and a circle, and locate objects in the interior, outside and on the border of real spaces;
- parts of traditional houses, like posts, beams and battens, can be used by the pupils as example for measuring and to compare lengths of concrete objects and of segments of straight lines, using the expressions *is longer than*, *is shorter than*, *is not as long as* and *has the same length.*

- using the holes in the ground for the house posts in houses of rectangular and circular base, pupils can learn notions of points, curved lines, straight lines and segments of straight lines;
- looking at a house wall (real or in photos) -- in rectangular based houses -- one can use posts, *(m)balilo* (battens), even *phalupalu* and battens in faces of roofs of *nsukuligóngwè*, *ramada*, *nhamagóngwè* and *góngwè* types, as examples for parallel straight line segments;
- under the conditions presented above, posts and battens in a wall are perpendicular, and *phalupalu* and battens in roof faces are also perpendicular, and one can identify right angles as well -- note that walls in brick-built houses have no battens;
- using the different methods used by the house builders to construct the rectangle and circle one can ask the pupils to indicate important properties of the rectangle and square, and identify and classify parallelograms using the most important properties, and draw circles knowing the notions of centre and radius;
- the "boxes" formed by the walls can serve as examples for the geometrical solids *block* and *cylinder*;
- in walls and roofs of houses of rectangular base one can identify faces and edges and study the relations between them;
- in faces of roofs of *nsukuligóngwè* and *nhamagóngwè* types, teachers can ask pupils to identify vertices, (acute and obtuse) angles and triangles;
- inspired by traditional houses pupils can draw segments, parallel and perpendicular straight lines using a ruler and *paper-square;*
- by looking at traditional houses (or their photos) pupils can be asked to identify and describe geometrical solids including the cone and pyramid (*nsukuli*), starting from observation of real objects, from drawings or from given description, as suggested in ISP-Beira (1993, pp. 13-17);

These were some of the examples of the relationship between the mathematics involved in traditional house building and the school mathematics of the grades 1 to 3 in Mozambique -- using real objects from the daily environment of many of our school children. *Is that not doing mathematics?*

8.4 Algorithm

In this section one shall present examples of geometrical algorithms both for the plane and for space geometry used in the traditional house building.

8.4.1 Eight methods to construct a rectangle

The researcher came across eight methods used to construct a rectangle, one of them not found in the Provinces of Zambézia and Sofala but only in the literature. One can divide the construction methods of a rectangle into two groups: (i) the so-called *traditional methods* -- the methods in which one cannot see directly the influence of the school mathematics or those methods known to be used already at the time of colonization -- these are the first, the second, the fourth and the eighth methods; and (ii) the *mixed methods* -- these are the methods in which one uses a set square.

.

Some methods are easy to use and others require more attention and competence in order to obtain the desired rectangle or square. One can demonstrate that from all eight methods a quadrilateral could migrate into a rectangle, that means that the builders were thinking in terms of mathematical methods, i.e., methods that can be translated into academic mathematics, to construct a rectangle. However some of them make mistakes, mainly when they use methods where iterations and/or approximations are used.

By the first, third and eighth methods the right angles appear exactly at the same time.

8.4.1.1 Are the house builder methods geometrically correct?

In this section the researcher would like to demonstrate the correctness of four methods or simply how one can use them to solve textbook problems in geometry. Thus, one will justify that these methods can be dealt with both in teacher education and in the classroom with school learners. The remaining four methods, that are also geometrically correct, will be tackled in a further section of this chapter, when the researcher presented them in a workshop.

1. For the *third method* the explanation presented in the section 6.1.2c, of the chapter 6, could be enough to demonstrate that this method is geometrically correct. It is one of the standard methods for rectangle construction used in our schools. Given that the opposite sides are equal one needs only to ensure that one of the angles becomes a right angle then, a parallelogram with a right angle is a rectangle.
2. The *fourth method* is also geometrically correct. On paper this method can be compared to the second method (see p. 167, Fig. 8.5). But, on the ground there is some difference.

   Whereas in the *second method* the stick keeps the side length of the square, in the *fourth method* the rope has to be well stretched in order to fix the side length.
3. The *fifth method* was sufficiently explained in the section 6.1.2e, and the comments presented there may be enough to show that this method can result

in rectangles, when correctly used.

4. The *eighth method* can also be used on paper. For that, one needs to have the measurements of the diagonal and of one of the rectangle's sides, in practices represented by a bamboo stick, and one has to know the rectangle properties that the diagonals of the rectangle are of equal length and cut each other in their midpoints. With these data and this knowledge one can first construct a triangle whose sides are the given side measurement and half diagonal (see figures 8.1a and 8.1b).

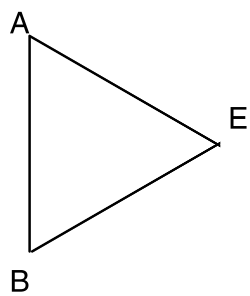


Fig. 8.1a

or

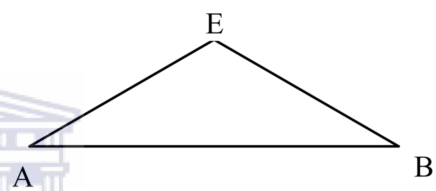


Fig. 8.1b

After that, one completes the diagonals (figures 8.2a and 8.2b). Finally, one can complete the rectangle (figures 8.3a and 8.3b).

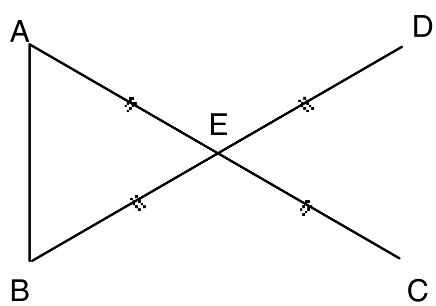


Fig. 8.2a

or

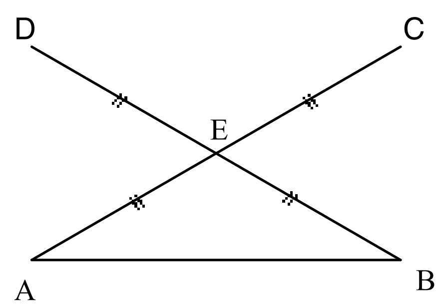
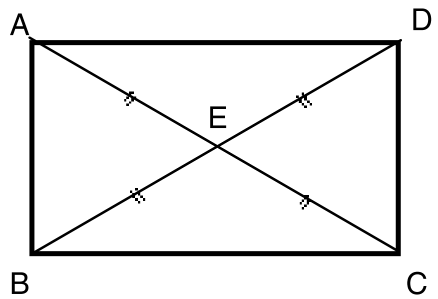


Fig. 8.2b



or

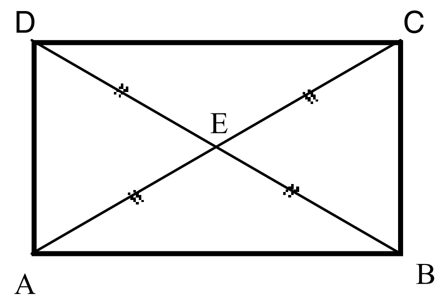


Fig. 8.3a

Fig. 8.3b

About this last method one can see generalizations and variations in Gerdes (1999, pp. 95 - 99).

8.4.1.2 How do junior lecturers and student teachers accept and deal with the house builder methods applied to textbook problems?

In this section the researcher will demonstrate the applicability of the remaining four methods used by the house builders to construct the rectangle.

Before making suggestions about *how the mathematics involved in the traditional house building can be incorporated in Mathematics Education in Mozambique*, the researcher organized a workshop involving the following two groups: (i) four mathematics junior lecturers who are now his colleagues, but who took Ethnomathematics classes from Prof. Paulus Gerdes with in the early 1990s, and (ii) five student teachers of the Pedagogical University, the University where the researcher is working. These students are in the Masters degree program in Mathematics Education but have not yet taken Ethnomathematics classes.

In this workshop the participants were dealing with mathematical ideas and knowledge related to traditional house building.

The main objective of the workshop was to test the sensitivity of some teachers and student teachers to out-of-school mathematics, in this case involved in the traditional house building. At this time the researcher had the data already collected and did also some data analyses.

First, the researcher presented to the participants of the workshop the theme of his research and its stage of development. Then, he explained to them the objective of the workshop in relation to the study (the thesis).

8.4.1.2.1 First part of the workshop

In the first part the researcher presented the research questions, the fields of the research and four of the eight methods for rectangle construction used by the house builders, viz. the first, the second, the sixth and the seventh methods (see chapter 6).

Then, working in four groups of two or three, the participants had to answer the question: *Is it possible to "transfer" these methods to the solution of textbook problems?*

One of the groups had not understood well the meaning of "to transfer" and was asking for measurements of the rectangle's length and width for the first method. The group would like to construct rectangles with given *concrete* measurements. But, that was not the *spirit* of the question posed above. The objective of the task was to imitate the methods used by the house builders in these formal textbook problems or applications -- that is, without poles, sticks or ropes.

After more explanation the groups worked for a while and then there was a general discussion around the four methods.

1. For the *first method* some groups began with the construction of a diagonal and one side of the rectangle but, as soon as the other participants began to ask

questions, they understood that they were on the wrong way.

Then, one came to the conclusion that, "given" the measurements of length and width, when one intends to construct a rectangle without set square and without any instrument to measure the angles, one have first to construct a parallelogram using a ruler and a compass. Then one changes successively the shape of the parallelogram measuring and comparing the diagonals using the compass span. When $AC_n = BD_n$, then $C_n = C$ and $D_n = D$ and the rectangle [ABCD] is constructed. (See figure 8.4)

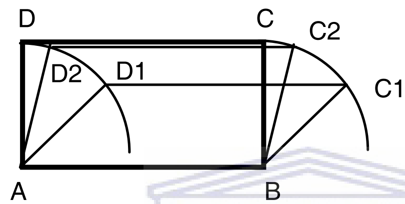


Fig. 8.4: The first method of rectangle construction using ruler and compass

A task like this can be very useful for the students. With this kind of tasks they can train drawing with "precision". It can also be a good example for the students that before starting, one has to understand the task well and then make a working plan. It turned out that even among the lecturers, some of the participants in the workshop, who started with the diagonals, constructed isosceles trapezium and not rectangle.

Note that the teacher can use a task like this to show the students that a quadrilateral with equal diagonals **is not necessarily** *a rectangle.*

2. The *second method* consists on constructing a square using a right pole, constructing the right angle with the naked eye. To do this construction on paper or on the black board (only given the size of the side) the participants needed more help from the researcher. Some groups draw a *rhombus*, not a

square. At the end one came to the conclusion that one can (**1**) use a set square for the right angles or (**2**) one can use the theorem by Thales of Miletus (c. 625 - c. 547 BC): *an angle inscribed in a semicircle is a right angle*. (See figure 8.5).

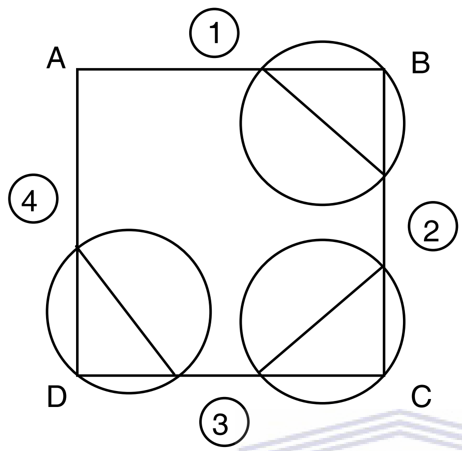


Fig. 8.5: Square construction using the Thales' theorem

Note that advanced students can use the Thales' theorem only twice, namely, in "B" *and in* "C".

In this workshop the researcher realized that even the lecturers never used the Thales' theorem to construct rectangles, even if they teach it -- the theorem -- to their students.

This task can be used to combat the misconception that a quadrilateral with four equal sides is a square.

Look that the house builder, using the second method, does not measure the angles -- he uses the eye. *How can one manage to construct right angles on paper without measuring them?*

In this study the researcher would like to suggest a way that one can be used to manage right angles without measuring them is the Thales' theorem using ruler and compass. Other ways one can draw a rhombus that only by chance can be a square. *Note that the use of a set square suggests already a direct drawing of the right angles, whereas by the Thales' theorem one comes indirectly to the right* *angles.*

3. The *sixth method*, given that one can use the set square three times to construct the rectangle, was an easy task to do on the black board or on paper.

4. The *seventh method* is an application of the *reflection symmetry*, being the middle point of the diagonal the *centre of symmetry*. So, the seventh method is also a mathematically correct method to construct a rectangle, even if in the real practice of the house builder, working on the ground with sticks and ropes, one doesn't need to determine the mid-point of the diagonals -- *the centre of symmetry*. Given the length (l) and the width (w) of the rectangle-to-be, on the black board or on paper, one can first construct a right triangle (Fig. 8.6a) and then apply reflection symmetry (Fig. 8.6b).

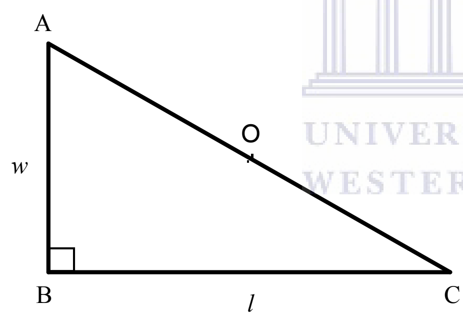


Fig. 8.6a

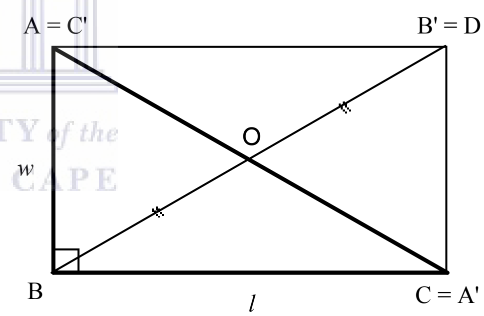


Fig. 8.6b

The difficulty among junior lecturers and student teachers in recognizing that the house builder was using reflection symmetry can be used as a good example to explain the meaning of psychological blockade, *this time in an inverted direction. In this case the teachers and student teachers are able to manage well geometrical transformations, like reflection symmetry, but when facing a new and informal approach used by the traditional house builders they are not able to recognize the application of reflection symmetry.*

Then, still relating to the workshop, the researcher presented a transparency with the seven names of the six roof types, namely: *Nsukuli* for round house (1) and square based house (2), *Nhamagóngwè* (3), *Góngwè* or *Magóngwè* (4), *Nsana wa ndzou* or *Ramada* (5) and *Nkhope ya kolo* (6), and the participants discussed the advantages and the disadvantages of each roof type, from the point of view of geometry.

One can emphasize that all participants considered the roof of *nkope ya kolo* type (one-sided roof -- see table 6.2) as the one with more disadvantages, especially because the front wall of a house with this kind of roof remains too exposed to wind and rain water. After that the researcher explained the "transition" from roof of *nhamagóngwè* type into *góngwè* type, in the second part of the workshop on the advantages in the inclinations of the roof faces. The workshop participants didn't see any difference in terms of advantages and disadvantages of each roof type. They only considered the roof from *góngwè* type as a very beautiful one.

The first part of the workshop ended with each individual answering the following questions, on paper:

1. Name: _________________________ Code: ☐
(Optional)

2. Academic level (concluded) _____________3. Age: _____

4. Are you a teacher? 4.1. Yes ☐ 4.2. No ☐

5. Which teacher education courses have you concluded, when, where and duration?

6. What has impressed most (positively/negatively) in the workshop?

7. Did you learn something new? If yes, please give details.

8. Did you think that something related to traditional house building can be "taken" into the classroom?

If no, say why;

if yes, give details of how that can be done. Give a few examples.

8.4.1.2.2 Second and last part of the workshop

For the second part of the workshop the researcher showed sketches of *góngwè* and *nhamagóngwè* roof frames (with short *nzati*s) with the question: *Why is the roof of* Góngwè *type?!...*

After some discussion the researcher presented more questions:

1. How many angles exist in the roof frame?
2. Which is the ideal roof inclination?
3. Which is the most advisable roof type for houses with rectangular base?
4. Any other question?...

After some discussion about the ideal roof inclination he showed the picture in Fig. 8.11 from a distance (see Fig. 8.11 in section 8.5.2).

All participants recognized pine trees in that picture, even closely.

After some explanation they were able to recognize houses with square bases and pyramidal roofs, and said that it could be very difficult to thatch such roofs in Mozambican conditions.

After some discussion around the incorporation of the mathematics involved in the traditional house building in mathematics education, the workshop ended with following questions, which were answered by all participants, individually:

1. Name: __________________________ Code: ☐
(Optional)

After the discussion answer again:

7'. Did you learn something new? If yes, please give details.

8'. Did you think that something related to traditional house building can be "taken" into the classroom?

If no, say why;

if yes, elaborate how that can be done. Give a few examples.

The individual answers to these questions, which are presented in next section resume the “content” of the discussion in the workshop.

8.4.1.2.3 What has the researcher learnt from the workshop?

All the participants of the workshop, both lecturers and student teachers accept the incorporation of out-of-school mathematics, in this case involved in the traditional house building, in school mathematics. They did not accept it superficially, but present their arguments. There were no significant differences between the arguments, comments and answers to the workshop questions by the lecturers or teachers and by the student teachers. Now one would like to present some responses and comments to three of the workshop questions -- that the researcher considered to be the most important ones.

6. What has impressed you most (positively/negatively) in the workshop?

(All participants were positively well impressed)

- The very clear approach given to the theme in which apparently simple aspects of the real life are “transferred” to mathematical thinking.
- The spirit of researching in “traditional” geometry impressed me positively. It represents an appreciation of the African culture.
- I’m very impressed — the house builders’ procedures contain mathematical knowledge, even if they don’t know that.
- Geometrical knowledge is applied in the practical life by the population in their daily life activities independent of knowledge about axioms, theorems, etc.
- The form in which non-schooling people use geometrically knowledgeable,

sometimes unconsciously.

- I'm positively impressed with the concern of trying to find out the geometrical knowledge used by the house builder. The reflection and discussion that we had in this workshop about how to bring to paper the methods used by the house builders are most of the time missing. Many people only say: *There is much geometry* but, they never manage to show this geometry.

7. Did you learn something new? If yes, please give details.

- Yes, I learnt something new. I learnt that our traditional societies, in rural areas, apply geometry in their skills by building houses.
- I learnt the different ways in which some communities from Zambézia and Sofala build traditional houses, for example, construct a rectangle comparing the diagonals.
- I learnt that many aspects of the elementary geometry taught at school can find arguments in practice.
- I knew some of the procedures to construct rectangles, but I found very interesting the method where one uses correctly the *reflection symmetry.* So, I can conclude that ordinary people can be a source of knowledge. This method, even at school is seldom used.
- The *return to the origins* can facilitate, in the first school grades, the process of teaching and learning geometry.
- I learnt that the roofs of traditional houses are not constructed haphazardly. There exists a relation between the roof type and the base of the house.

8. Did you think that something related to traditional house building can be "taken" into the classroom?

If no, say why;

if yes, elaborate how that can be done. Give a few examples.

All participants answered with yes. Now some of the suggestions given by the participants of the workshop will be presented. The researcher repeated questions 7 and 8 in order to see if it could have any change of mind after some discussion but this was not the case.

- By rectangle construction — to substitute the four sticks, each two of the same length, with a ruler, and to substitute the rope (to measure the diagonals) with a compass is a beautiful mental and geometrical exercise.
- Stimulating the students in using "traditional" models to make their knowledge real and relating this knowledge with the existing geometrical axioms and theorems.
- Discuss with the students, in the classroom, about the types of traditional houses they know. Identify the existing shapes and the geometrical properties in a subsequent representation on paper. The different methods to construct a rectangle are very interesting.
- Many times there are a disparity between what is taught, how it is taught and that what the students know.
- Construct rectangles without constructing directly the right angles, using other properties of the rectangle.
- The student teachers could stimulate reflections in their pupils about, for example, the relation between roof inclination and its duration, given that this knowledge is useful for the communities. This kind of reflection can reduce the idea that mathematics deal only with "school issues" or with issues from the "West".
- One can deal with traditional house building like we did in this workshop. The new school syllabus reserves space for this kind of issues.
- The teacher with his/her students can solve school tasks inspired by the activity of traditional house building, so that the students recognize that the mathematics that they learn at school is not something "imported", that it is something that they live in and live with in their daily lives.

One can see that many of the answers to the questions 7 and 8 are an attempt to answering the question by Gerdes: "Where do (early) geometrical ideas come from?" (Gerdes, 1995a, p. 29).

When one of the participants of the workshop wrote that "the *return to the origins* can facilitate, in the first school grades, the process of teaching and learning geometry", *he is saying and recognizing at the same time that the geometrical ideas come from practice, from human daily life activities*.

So, one can say that all eight methods for rectangle construction used by Mozambican traditional house builders have mathematical foundations.

8.4.2 Circle construction

The method to construct the circle is presented in section 7.1.1, chapter 7. By the view of the researcher, the procedure, in which one uses two pegs and a rope or string, is the more direct application of the definition for circle and is easier for beginners in geometry to study, than the use of a pair of compasses. When one looks at the definition of circle: **"A plane curve that is the locus of a point which moves at a fixed distance (the radius r) from a fixed point (the centre)"** (Dainitith and Nelson (ed.), 1989, p. 54), the "fixed distance" is materialized in the rope or string, while *(the fixed distance)* is invisible when one uses a pair of compasses.

8.4.3 Placing posts and beams

Empirical notions of verticality and horizontality

It can be demonstrated that the methods to place posts result in the posts being vertical to the plane of the ground, even if the ground at that point is not level.

It can be said that a post is vertically (well upright) placed -- ***wimela dereto,*** in Echuwabu or ***walungama,*** in Cisena -- when the methods described in section 6.2.1, chapter 6, are correctly applied. This means that the post will have the same direction of the straight line representing the *force of gravity.*

The demonstration of this conclusion cannot be only geometrical. It is both psychological/physiological and geometrical. It has to do with visual imagination. First, one can start from the view point that it is acceptable to recognize that the sense of verticality is something natural, something intuitive, which one is born with. It (the sense of verticality) is going to develop as one grows up. When someone, even a child, is trying to stand up with the feet at different levels of the ground, he does not need a long while to think that he must not stretch both legs. *Is this reasoning acceptable?* -- Asks the researcher.

It is this sense of verticality that helps someone to decide if a stick or a tree trunk is upright or not, at least related to the plane in which his body and the base of the stick or of the tree trunk are. The researcher is referring to a standing body, because, when the person is not standing up the question of discussing if a certain object is upright or not becomes more complex, and will not be discussed in the thesis. (As shown on figures 8.7a and 8.7b, (v) means that the indicated stick is vertical and (nv) means that the stick is not vertical.).

School children are able to recognize vertical and non-vertical sticks in space (see interviews in the Appendix C).

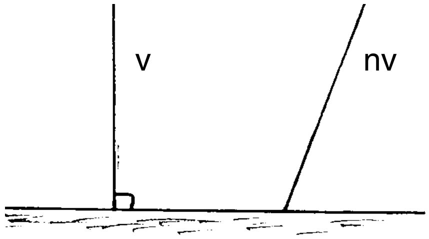


Fig. 8.7a

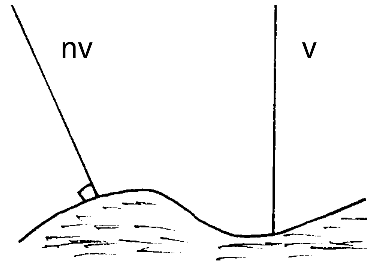
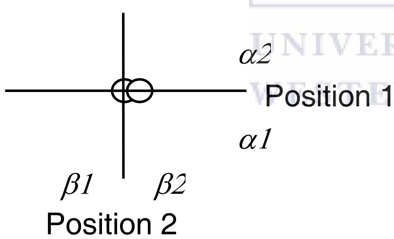


Fig. 8.7b

Four school children were submitted to an interview in which they had to recognize vertical and non-vertical sticks, justifying their decisions. The interviews took place on the beach in order to avoid the influence of artificially vertical objects. It is evident that, even if not consciously, all of them have been confronted with real situations related to verticality in the space. But, it was the first time for them -- with the interviews -- to “play this game” and they have not experienced it neither at school nor at home -- in the children’s words.



Plan of the positions to decide on
the verticality of the post

Fig. 8.8a

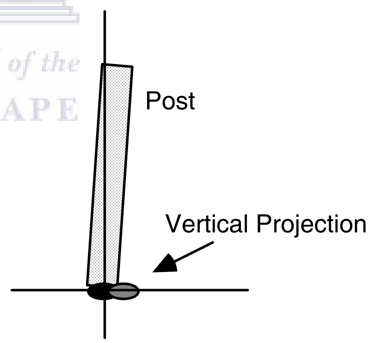
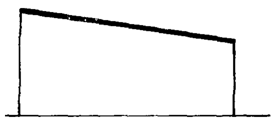


Fig. 8.8b

Seen from position “1”, Fig. 8.8a, the post seems to stay in the upright position. But from position “2” (Fig. 8.8a and Fig. 8.8b) one can easily see that the post is inclined to the right side.

The question of horizontality of the ground is also naturally developed but to decide if a stick or a tree brunch is in the horizontal position needs some *training*. The researcher recognized this difficulty from experiences with children in constructing football goals using precarious materials. For some of them it was not easy to decide if the crossbar of the goal were in the horizontal position (in Echuwabu, *oguaguanyea*) or not, that is, if both posts of the goal were of the same height or not. (Fig. 8.9a and Fig. 8.9b). On ground that is not level the crossbar can be in the horizontal position, but with one post longer then the other one. (Fig. 8.9c).

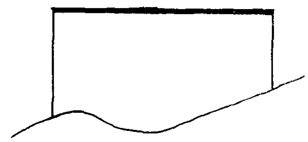


Level ground: not horizontal crossbar

Fig. 8.9a

Level ground: horizontal crossbar

Fig. 8.9b



Not level ground: horizontal crossbar

Fig. 8.9c

The house builders from the areas of research in Sofala and Zambézia Provinces are able to put a beam in horizontal position, even if the ground is not very level. For that they use the first method (see Fig 6.18 in the section 6.2.2., chapter 6). *Is this reasoning not mathematically based?* -- Asks the researcher.

8.4.4 Approximation/extrapolation and experiment

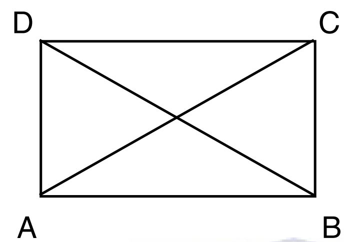
In the process of traditional house building some extrapolation could be found. For example, the first, second and the fourth methods for rectangle construction are methods where one uses “trial and error”. *Can one see that as approximation or extrapolation?!* Even the methods for placing beams and posts are of a “trial and error” nature. But this approximation doesn’t simply occur. The result is not a by chance “thing”.

The house builder knows what to do in each situation. Look at the example of the house builder Sualé (see “Interview Zambézia-1” from 05/07/97, in Appendix A):

Interviewer: the researcher

Daniel: — Imagine that you are using the method that I can call "of the diagonals" and in the measurements you notice that AC is bigger than BD. *(See the figure — the quadrilateral [ABCD] was represented on the ground through 4 sticks)*. How could you proceed to put it right?

Sualé:



If AC is bigger, then I will push from here into interior *(indicating the vertex C)* so that the corner A doesn't move.

I measure again. If at that time BD is bigger, then I push from B or from D into interior leaving the corners D or B fixed, respectively. I repeat this procedure until the two measurements, AC and BD become equal.

This procedure is geometrically correct. In fact, when one pushes from C into interior leaving the corner A fixed, the diagonal AC -- that is the longest -- will decrease its length, whereas BD -- that was the shortest diagonal -- will increase its length approximating the lengths of both diagonals, AC and BD. Could we recognize that this house builder used consciously the first method of rectangle construction?

To decide about the inclination of the roof one uses an experimental approach. One ties a rope at a certain height of the *nzati-to-be* pole and stretches it to the beam. One changes the position of the rope on the pole until the house builder finds the advisable inclination for the future roof. So, one cuts the pole with the necessary height and fixes it well in its hole, becoming *nzati*.

8.5 Problem solving: Application of folk mathematics?

In the traditional house building one can find situations in which the house builder has to solve problems. In this section one will present four situations. One can, however, consider that the application of the algorithms presented above have also a lot to do with problem solving.

8.5.1 Discussion on roof types

One of the most important structures of a traditional house is the roof. When one wants the roof to last for years it must have the same inclination in all its faces. That was only possible with the roofs of types *nsukuli* and *ramada* (*nsana wa ndzou*); the latter for houses with rectangular base, given that *nhamagóngwè* type has each two opposite roof faces equally inclined, but not all four equally inclined (see Fig. 6.45 in the section 6.4.4.2, chapter 6). But, as said in chapter 6, roof of *ramada* type must be constructed in regions where one knows very well from which side or direction the strong winds blow. Because, when a strong wind blow from a house's side where there is no roof face, the roof can be lifted and destroyed by the power of the wind. That means that the roof of *ramada* type, could be a provisional roof solution for houses with rectangular base. So, the solution for that situation comes with the invention of the roof of *góngwè* or *magóngwè* type (see section 6.4.2.2,).

In this roof type one has nearly equally inclined roof faces and the roof is four-sided. On the other hand, the roof of *góngwè* type avoids the use of very long *phalupalu* coming from the only one apex (in roof *nhamagóngwè)* to the beams that could create pools in the faces of the roof. This subject will be broached in sections 9.1.3 to 9.1.5.

8.5.2 Which is the best inclination for the roof

As previously mentioned in the section 6.4.4.4, for any roof, the bigger inclination means the bigger speed with which the rain water falls from the roof. In Figure 8.10 it is evident that as the height of the *nzati* increases the triangular face of the roof of *nhamagóngwè* type increases also in height and thus reducing the base. But the height increases more than the base is reduced, i.e., when the roof inclination increases, the face of the roof increases in area, which means more construction materials and also bigger area exposed to the wind and, in turn, has a negative impact on the durability of the roof thereof. So, mathematically seen, when the *nzati* increases indefinitely in height, the area of the roof increases also indefinitely, i.e., from this point of view, there is no recommended inclination for roofs from types *nsukuli, góngwè* and *nhamagóngwè.*

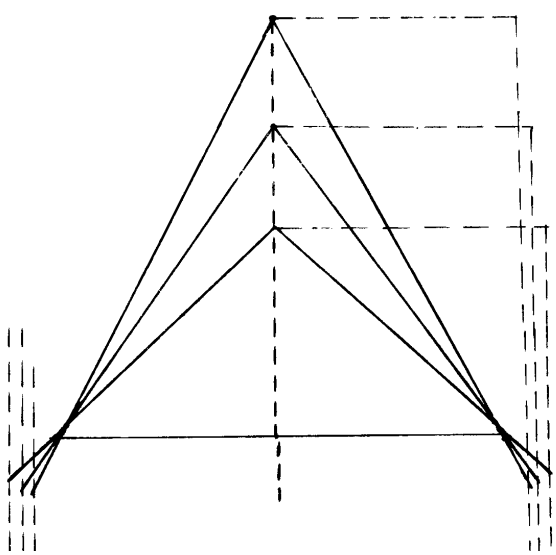


Fig. 8.10: Scheme of a triangular face from roof *nhamagóngwè*

So, it is very difficult to determine the best inclination for the roof, principally because the traditional houses have roofs liable to deterioration. As the house builder said, when the inclination is too big, the house builder who is constructing the roof can fall down, especially while thatching, but by reducing the inclination the roof could result in more rain water stalling on the roof and permeating to the interior of the house.

For one-sided roof -- *nkhope ya kolo* (see Table 6.2 in the section 6.4.1) – a bigger inclination of the roof can expose the front wall to rain water. *What to do now?* That can be the question that a house builder can ask himself. *Which could be the answer or the solution?*

In practice -- using measurements -- the roof inclinations in Zambézia and Sofala Provinces vary according to following angles:

- roof *nsukuli (square base)*: 30° — 45°;
- roof *nhamagóngwè*: 25° — 50°;
- roof *góngwè*: 30° — 45° and
- roof *nsukuli (circular base)*: up to 60°.

The researcher is not sure that these are the best inclinations, but he agrees with Gerdes, when he wrote that

> ... the forms of the objects are almost never arbitrary, but generally possess many practical advantages, and are, a lot of the time, the only possible or the optimal solutions of specific production problems, ... (Gerdes, 1995a, p. 29).

In this specific case of roof inclination, the researcher is more after "optimal solutions", than for "the only possible solutions".

For further reflection or reasoning on roof inclination one would suggest to analyze the following situation:

- Look at the following picture (Fig. 8.11).

• What can you recognize?

As said at the beginning of this chapter, the questions in this chapter have an objective to invite the reader to think together with the researcher over different problems and situations related to traditional house building that can have relation with mathematics.

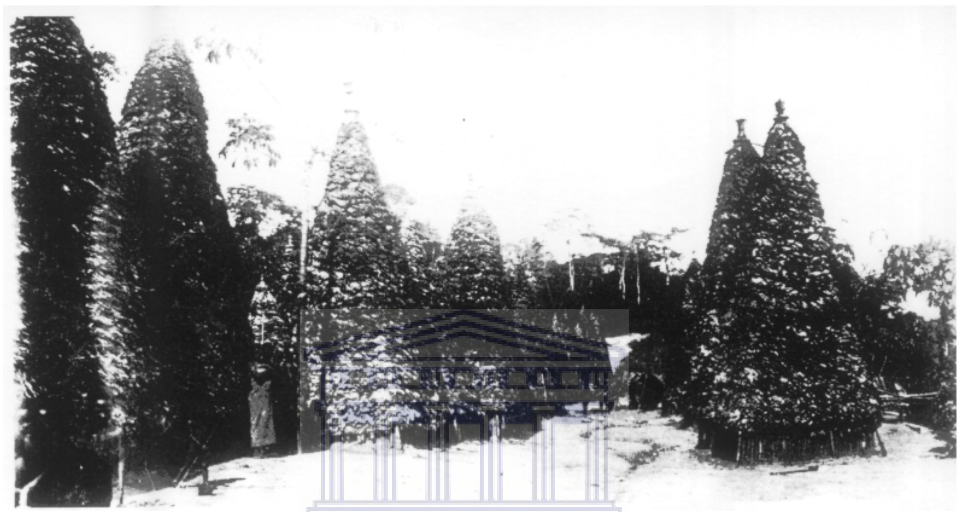


Fig. 8.11 In Denyer (1978, p. 59)

If someone recognizes pine trees in this picture then, they are wrong!... Actually these are roofs found by the *Ngelima*, Kisangani, Zaire (at present DR Congo), in about 1905. There are very high roofs thatched with large leaves. A closer look at the bottom of the house on the right clearly shows the walls of a square based house.

The *Ngelima*

> ... live between the Aruwimi and Lindi rivers, tributaries of the River Zaire. This humid district is at the heart of the high rain forest where there is over 100 mm of rain most months of the year. Each of the houses in the village was about 2 m square. The walls rising to about 1.5 m, were made of wooden poles, while the pyramidal roof was carried to about 6 m. It was thatched with large leaves fastened in horizontal rows against a frame of

basketwork. (Denyer, 1978, p. 59).

This example is in accordance with the conclusion in the section 6.4.4.4, that in the inland, where the sun rays penetrate with difficulties and at the same time it rains often, the roofs have bigger inclination. That, in turn coincides with a conclusion by Frobenius about Bantu traditional houses in central Africa, when he, right in the XIX century, wrote: "These have generally higher roofs than those from the seaboard people, ..." (Frobenius, 1894, p. 45). So, one would dare to conclude that the roof inclinations, which our house builders use (in parts of Sofala and Zambézia Provinces), are the "optimal solutions", under the specific conditions of climate and available building (and thatching) materials.

8.5.3 Circular base and top of walls: An interesting challenge

The traditional house builders from Sofala Province, who build houses of circular base showed us that they are interested in perfection. They try hard to get cylindrical walls when they transfer *makassa* made on the ground to the top of the posts so that the circle determined by the posts on the ground and the one to be formed by the beam at the top of the posts are equal (see section 7.1.3, chapter 7). *How can we, as mathematicians, interpret this transference of* makassa *from ground to the top-end of the posts?* Mathematically seen, one can consider this as *vertical translation* (an isometric transformation) *in space*, from bottom to the top, the length of a post being the module of the translations vector.

8.5.4 Bathroom outside the house -- with doorless entrance

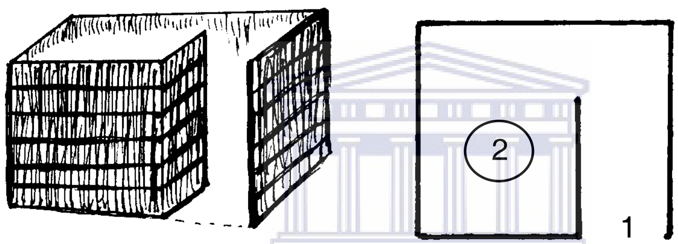
Both in Zambézia and in Sofala Province one builds bathrooms outside the houses at a distance of between 5 and 20 meters, in the back yard. These bathrooms have no roof or door (but have an entrance). The doorless entrance is so constructed that the one who is bathing inside cannot be seen from outside. Many reasons could have determined why one came to this solution. (See figure 8.12)

Looking for mathematical aspects it can be said that three geometrical aspects are important to guarantee the privacy of the bathroom's user:

— the height of the walls;

— the location and width of the entrance, and

— the width of the internal (semi-) wall.



Bathroom plan 1 - entrance
2 - bathing place

Fig. 8.12: Bathroom

While being an interesting and useful design, there is once again no scientific evidence that the house builder who invented this kind of bathroom was thinking mathematically.

Thus, one has presented four examples of situations in which the house builder had to solve practical geometrical problems.

8.6 Orientation of the houses

The orientation of the houses varies according to their location in either the interior of the country or near the coast. In the interior it is more difficult to speak about the orientation of the houses. There, the houses are built in groups. The head of the family has the biggest house and the other houses are so built that they face the biggest house separated from them by a (central) courtyard. Generally they have no fences. In this case the houses have mostly only one door. In the savannah plane lands and near the coast we have two main references: the main road and the sea. So, the location of the door is a function of main road and sea. It is natural that one can find exceptions.

8.6.1. In reference to the main road

In most cases the main doors face the main road. Sometimes people use the main doors only for guests. In these few cases one uses the back doors for the daily activities in order to keep some privacy. In each case the most beautifully doors face the main rood.

8.6.2. In reference to the sea (Indian Ocean)

Generally the houses have two opposite doors. The back door looks to the sea. During the day both doors are kept open in order to guarantee freshness in the interior of the house. For the houses of two-sided roof this position is the best one, given that in this position the houses can better resist strong sea wind. As one can see a house builder needs to have at least some empirical knowledge of mathematics, physics and geography (climate and geology).

8.7. Fractions

In southern Zambézia, the posts for traditional house building are, generally, made of coconut palm tree. For that, a big coconut palm trunk is cut in pieces to the desired length for the posts. The pieces are cut in two halves (Fig. 8.13a).

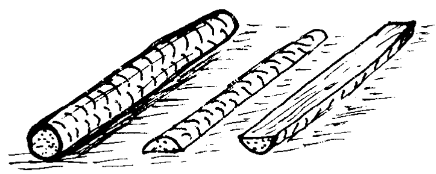


Fig. 8.13a

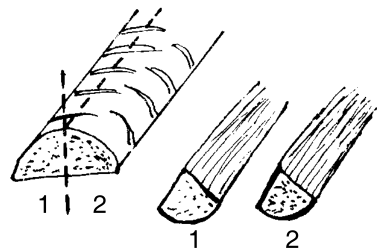


Fig. 8.13b

Depending on the radius of the cross-section each half can be divided again in two or three parts (figures 8.13b and 8.14).

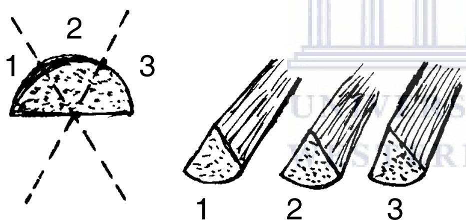


Fig. 8.14

Here one can see that $\frac{1}{2} = \frac{2}{4} = \frac{3}{6}$. More explorations can be made.

These last pieces are worked out in order to obtain posts from type c) (see section 6.2.2 — *post made of coconut tree timber or other well worked timber*).

Behind the decision of dividing each half in two or three parts, for the production of two or three posts is hidden the knowledge of "circle inscribed in a triangle", even if in this concrete case it is about a circle inscribed in a sector and not in a triangle. The circumscribed circle represents the cross-section of a post.

The introduction of fractions representing the pieces could be a didactical *use of the situation with fractions above.*

8.8 The Golden Ratio

As one looking for mathematical concepts in the study of the traditional houses, it is farfetched to look for ratios relating the measurements of the various parts of a house such as length and width of rectangles like the house bases, the doors, the windows and the rectangular walls. One of the most common relationships between numbers is the golden ratio, known as the first discovered non-rational number, with many revelations in nature and in artifacts. Remember that the golden ratio is represented through the number $\varphi = \frac{1+\sqrt{5}}{2} = 1{,}6178...$

There is quite frankly no scientific reason why one expect the golden ratio to emerge from among the various measurements other than the excitement its emergence would generate. From more than 20 measured rectangular house bases one found only four (in Nhamatanda -- Sofala) with a ratio close to golden ratio:

length (m)	width (m)	ratio (length/width)
5	3	1,6666...
5,65	3,40	1,6617...
5,85	3,50	1,6714...
5,75	3,40	1,6912...

Among the walls, one found in a small wall over the width of a rectangular base, in Dondo district — Sofala Province:

length (m)	width (m)	ratio (length/width)
3,4	2,2	1,54(54)

Among the rectangles along the brims of a small *nhamagóngwè roof* one found again in Nhamatanda district:

length (m)	width (m)	ratio (length/width)
4,75	2,9	1,6379...

In Zambézia, locality of Maquival, among the measured houses ratio numbers close to golden ratio appear in the doors:

length (m)	width (m)	ratio (length/width)
1.5	0.85	1.7647...
1.30	0.75	1.7333...
1.75	1.1	1.5909...
1.30	0.80	1.625

The house builders said that the door size depends on the house size, owner's size and the kind and size of the movable property.

8.9 How to determine the necessary material quantity for a house? A geometrical abstraction

Even before drawing the base of the house, the house builders are able to calculate the necessary material for a traditional house. They can say that *"x"* beams, *"y"* posts and *"z" kokotelo* (thin sticks placed vertically between wall posts) are sufficient for a house with *"m"* rooms. Unfortunately one was not able to understand how they calculate. They are able to calculate, rounding up through their experience.

They measure the *kokotelo* and *mbalilo* (battens) in square meters (see Fig. 8.15) -- of the cross-sections.

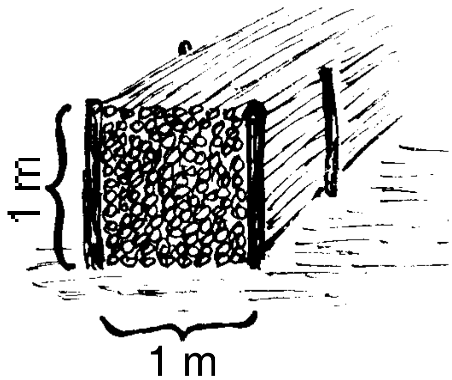


Fig. 8.15: square meter of *kokotelo*

During an unstructured conversation with the house builder Sualé and his brother Yassine, Maquival on the 14th April 1999, he said that the size (diameter of the cross-section) of the *kokotelo* is very important. He explained that the thinner the *kokotelo* is, the bigger the wall area that can be covered.

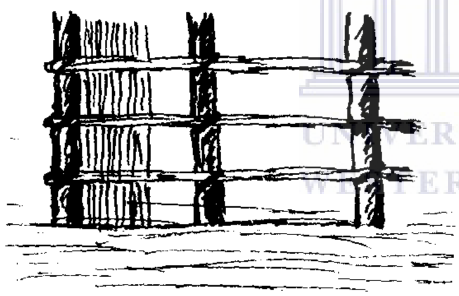


Fig. 8.16: part of a rectangular wall with three *mbalilo* and some *kokotelo*

- Look that the cross-sections are circular. Is the house builder right?
- Could you demonstrate the correctness of your answer?
- What can happen when the *kokotelo* cross-sections are squared? And when they are triangular (maybe equilateral triangle)?

These are leading questions, which will be answered in chapter 9, section 9.1.9.

8.10 Symmetries

As one knows, a figure or expression is said to be symmetric if parts of it may be interchanged without changing the whole. In the traditional house building one can find some symmetry.

When one looks at the bases of the houses one can see a lot of symmetries. For example, for the rectangular base one has *reflectional symmetry* (see the application in the seventh method for rectangle construction section 6.1.2g) and *two line* or *plane symmetries* (Fig. 8.17); for the square base one has reflectional symmetry and *4 line symmetries* (Fig. 8.18) and for the circular base one has reflectional symmetry and *an infinity of line* or *plane symmetries*, given that for the circle any diameter is an axis of symmetry.

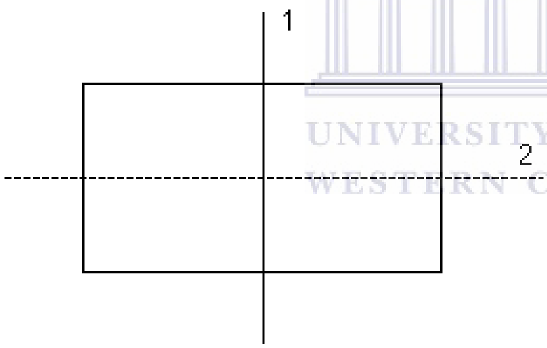


Fig. 8.17: Two line symmetries

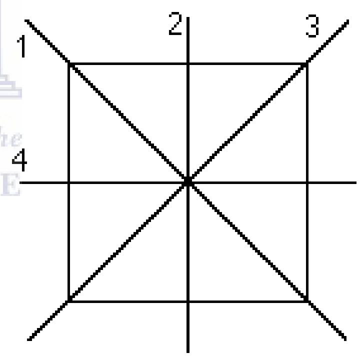


Fig. 8.18: Four line symmetries

Regarding the roofs one has the following situations:

- For the roof *nsukuli* (cone) one has an axis of symmetry. The *nzati* is the rotational axis.
- For the roof *nsukuli* (right square pyramid) one has *4-fold rotational symmetry*, the *nzati* is the axis.
- For the roof *nhamagongwe* one has *2-fold rotational symmetry*, being the *nzati* the axis.
- For the roof *gongwe* one has also *2-fold rotational symmetry*. The rotational

axis is a vertical line through the centre of the rectangular base and the midpoint of the *ntanda*.

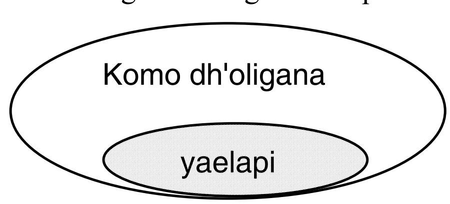
8.11 Direction angles

Regarding the methods of placing posts, specially the first method (see section 6.2.1a), and analyzing from a higher level, not at primary school level, one can say that the house builder works with direction angles. One has to remember that for a line (in this case the post is the line) in a three-dimensional coordinate system, *the direction angles are the three positive angles the line makes with the three coordinate axes* -- usually named by α, β and γ, for the axes x, y and z, respectively. The post is upright when $\gamma = 0°$.

8.12 The relation between square and rectangle in Echuwabu

For the Echuwabu speaking house builders *a quadrilateral with four equal angles is a square* (komo dh’oligana = equal angles or corners) -- maybe in similarity to a triangle with 3 equal angles (*equiangular triangle*), that is at the same time *equilateral triangle*. Thus, when the Chuabo house builders want to say that a rectangular base is not a square, they say that the base is *yaelapi* (*of* or *with length*), meaning that this time there are sides longer than the other sides.

So, in Echuwabu the rectangles belong to the squares and not the opposite.



In Echuwabu the rectangle is an “adulterated” square. So, *the square*, that has many geometrical properties, *is perfect*, whereas the rectangle keeps only some properties of the square. This situation can be interpreted as an example of *non-standard mathematics*, and one is in the presence of a mathematical form that is distinct from the (in *academic mathematics*) established pattern.

8.13 The African origin of rectangle in house building

There is sufficient evidence that our traditional house builders constructed the rectangle before the arrival of the European. For example, one can agree that the Echuwabu speaking house builders developed houses with rectangular base (square and rectangular) independent of non-African influences. Given the names of these shapes, one can suppose that they -- after the circle -- first developed houses with square base *(komo dh'oligana)* and then with rectangular base *(ya elapi)*, which is a "lengthened" square. Maybe one must agree with Frobenius when he writes that the rectangular base reaches the central and *eastern* Africa through the maasai (an African tribe), from the north. (Frobenius, 1894, p. 49). Unfortunately, this author doesn't explain when the maasai reached the eastern Africa.

Maybe, with the influence of the Portuguese (from 15th century) or of the Indians or Arabs they "began" (or restarted?) to construct sheds for shade (called *muthengo* in Echuwabu). The circular base of the *muthengo* is called *yarodondo* or *warodondo* which is an adulteration of the portuguese word *redondo*, meaning round or circular.

One can ask about how one calls circle in pottery in Echuwabu, a socio-cultural activity with an age of thousands of years. The answer would be that in general all pottery utensils have circular borders and that one names them according to their use and not their shapes.

Another phenomenon which reinforces most of the researcher's "conclusion" that the Echuwabu house builders developed houses with rectangular base without European or Arab influence is the fact that they developed special thatching material for houses with two-sided roofs (which one cannot use for conical roofs). The thatching material, made of woven coconut palm leaves (see Fig. 8.19), is called *nyoka* and has no translation into portuguese. (In Zambézia lies one of the biggest coconut palm plantations of the World). The same material is used in some Asian countries, like India, but there this material is called *tchantane.* There is no similarity between the names *nyoka* or *nhoka* and *tchantane*.

Fig. 8.19: Process of *nyoka* weaving -- from coconut palm leaves

Maybe the Chuabo house builders built earlier houses of circular base, given that they lived near the boundaries of the Monomotapa or Munhumutapa Empire where round stone houses (madzimbabwe; sing., zimbabwe) were built. According to Elleh

> more than 150 madzimbabwe ... of this kind were constructed by the Shona over a period of centuries in Mozambique and Zimbabwe ... These stone structures make up some of the traditional architecture of the Mozambican people. (Elleh, 1996, p. 191)

However, even at that time, they were already familiar with the rectangular shape, given that most of the stones used for the construction of the round walls were block-shaped, also with rectangular faces. (The researcher visited the historically famous city of Great Zimbabwe.).

The growth of the family size in the third world, the evolution of the furniture in type and quantity, forced people to build bigger houses. So, the house types were exposed to transformations in size, wall- and roof-shape, that led to rectangular houses.

Might the African names nkhope ya kolo *and* nsana wa ndzou *for the houses with one- and two-sided roofs* -- houses with rectangular base -- *not be a proof for the African origin of the rectangular base for the houses?*

The traditional woven sleeping mats are rectangular. Even animal hides, serving as sleeping mats are of almost rectangular shape, and that brings difficulties when these have to be accommodated them between round walls.

8.14 Sequences and non-ordinary functions

Sequences can be derived from wall constructions. In the process of house building the house builder is confronted with some functions. In this section one will only show that from traditional house building one can extract sequences and non-ordinary functions. Suggestions on how these sequences can be applied in the class room will be given in chapter 9.

8.14.1 Sequences

In the suburbs of Quelimane city, some houses have fences made of sticks and reed bundles. The sticks may not be very straight like the sticks used for the house building (for the wall or verandah posts).

After the fence frame was ready, a young house builder took a reed bundle and put on the frame in a vertical position. Then he cut the reed bundle to the desired length (corresponding to the height of the fence). Next, he cut the thin part of the remaining reed bundles using the first one as gauge. Finally, the reed bundles where placed in and tied to the frame of the fence in the upright position. Some bundles were (and are) placed with the thin end up and the other with the thin end downwards, in a not very regular pattern.

The researcher took seven intervals between fence sticks, which are not necessarily equidistant. One will look at bundle sequences in the fence, from left to right. The number 1 will represent a reed bundle with the thin end upwards and the number 2 will represent reed bundle with the thick end upwards.

a)	1	2	1	2	1	2	1	2							
b)	1	2	1	2	2	1	2	1	2	2	2	1	2		
c)	1	2	1	2	1	2	1	2	2	2	2	2			*)
d)	1	2	1	2	1	2	1	2	1	1	2	2	2		
e)	2	1	2	1	1	2	1	2	1	1	2	1	2	1	2
f)	2	1	2	2	1	2	2	1	2	2	1	2	1	2	1
g)	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1

- Look to the sequence b). What is your comment?
- Look to the five last terms of the sequence c). What can that mean?
- Could you find a general formula for each sequence?

In that interval (*) of the sequence c), the right stick was a pole with the top tilted into right side. In order to fill in well the interval between the two sticks in the fence, it was necessary to place more reed bundles with the thick end upwards.

One could also decide that the bundles with the thick end upwards are represented with (-1). So, we could have the sequences:

a)	1	-1	1	-1	1	-1	1	-1							
b)	1	-1	1	-1	-1	1	-1	1	-1	-1	-1	1	-1		
c)	1	-1	1	-1	1	-1	1	-1	-1	-1	-1	-1			
d)	1	-1	1	-1	1	-1	1	-1	1	1	-1	-1	-1		
e)	-1	1	-1	1	1	-1	1	-1	1	1	-1	1	-1	1	-1
f)	-1	1	-1	-1	1	-1	-1	1	-1	-1	1	-1	1	-1	1
g)	1	-1	1	-1	1	-1	1	-1	1	-1	1	-1	1	-1	1

- And now? Is it easier to find a general formula for each sequence?

8.14.2 Non-ordinary functions

In the process of house building one can find also examples of functions. For example, the direction in which a house faces can be a function of the prevalent wind direction and the position of the main road. One can even find examples of functions with more than two variables. For example, for any roof, the inclination of a roof depends on wind, rain and construction materials.

In the next chapter, Chapter 9, an indepth analyses will be made on about how the researcher thinks that the mathematical knowledge identified in the traditional house building can be incorporated in Mathematics Education. Some of the questions and tasks put in this chapter (chapter 8) will be answered and solved in the next chapter (chapter 9).

9. How can the mathematics involved in traditional house building be incorporated in Mathematics Education?

In this chapter the researcher will suggest some tasks and solve part of them. Question are likely to arise about some of the tasks that the researcher will put forward, on whether they are suitable for Mathematics Education in schools or merely for teacher education. On one hand it is not easy for the researcher to say which tasks can be dealt with in teacher education and which ones are ideal for mathematics education in school. On the other hand the researcher defends the viewpoint that a student teacher must be able to deal directly with pupil's tasks during his/her professional education like, for example, to fold and stick, by making space or three dimension models for the study of geometry.

As teacher educator the researcher would like to develop examples of tasks intended for teacher education, but given that the final objective of teacher education is to make mathematics more accessible, more understandable for the pupil, he has always been the tempted to develop tasks more related to mathematics education in school, or school mathematics, being inspired by traditional house building.

However, it will not be possible to indicate the school grades in which one can deal with each suggested task as that will be a teacher's issue.

Examples of the structure of some Mathematics Teacher Education Theme or Didactical Units into which ethnomathematics is included will be presented, but the introduction of new curriculum for Basic Education in Mozambique (grades 1 to 7), started in 2004, will have implications in teacher education curriculum. The new curriculum for the Basic Education was gradually introduced: in 2004 in grades 1, 3 and 6; in 2005, in grades 2, 4 and 7; and in

2006 in grade 5. It is also still at an experimental phase. So, the new curriculum needs still to be evaluated. The researcher agrees with Borba when he (Borba) writes that "… curricula cannot easily be changed by simply substituting some content for others. It is necessary to consider more fundamental kinds of change." (Borba, 1997, p. 269).

Thus, the researcher will restrict his main contribution to (**i**) indicating which mathematics is involved in traditional house building (chapter 8), and (**ii**) suggesting some tasks which can be used in mathematics education in school, including teacher education (chapter 9).

Before making suggestions the researcher organized a workshop with four mathematics junior lecturers and five student teachers of the Pedagogical University.This workshop dealt with mathematical ideas and knowledge related to traditional house building.

9.1 Some general tasks inspired from house building

In this section the researcher will present some tasks (not only related to geometry) that can be used in mathematics classes, both at school and in teacher education. In practical terms, knowing the situation and the background of the class is important so that more open ended questions may be asked during the class discussions. This allows each student to bring in his mathematical (even ethnomathematical) ideas and cultural practices to the classroom thus facilitating student-student and student-teacher interactions. In such work, memorized skills may not automatically work to answer the questions. On the other hand, forced exercises or tasks can seem too artificial. As Orey and Rosa (2006) write, "… ethnomathematics seeks to recognize the contributions, values, rights, and the equality of opportunity of all cultural groups that compose the given society"

(Orey and Rora, 2006, p. 73).

9.1.1.a Rectangle construction

One can ask the question: How many methods of rectangle construction do you know? Describe them. This task has as objective to make a survey on school and out-of-school methods the students may know, in order to relate them with the methods used by the house builders.

9.1.1.b Rectangle construction given the diagonal length

Given two equal long diagonals, one can ask the pupils to construct a rectangle. This task is inspired by the *first* and *eighth* rectangle construction methods. Working on a graph paper (Fig. 9.1) the pupils can easily realize or discover, or even find out, that the equality of diagonals length is not a sufficient condition to get a rectangle (or square).

To get a rectangle, apart from the equal long diagonals, one needs equal opposite sides (first method of rectangle construction) or the two equal long diagonals may meet in their mid-points (eighth method of rectangle construction). Notice that in Fig. 9.1 only the quadrilaterals d*,* e *and* f *are rectangles,* d *also being a square.*

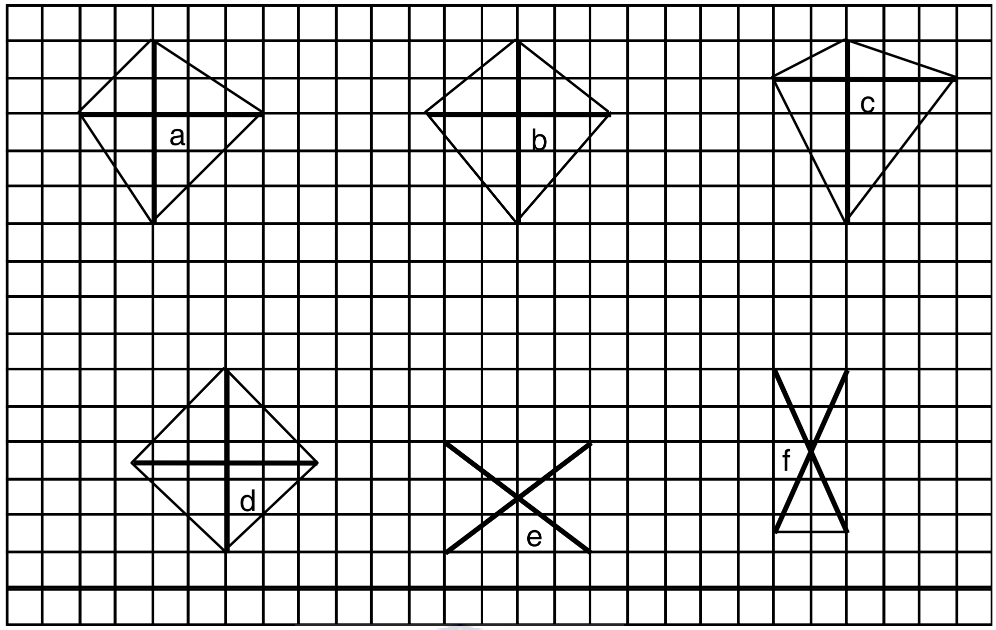


Fig. 9.1: Quadrilaterals with equal long diagonals

9.1.2 About conical roof (*nsukuli*)

About the conical roof one can suggest a task like the following one.

A conical roof has an inclination corresponding to an angle of 60°. The rain water, on a windless day, falls 40 cm away from the mud wall. If the *nzati* is increased by 50 cm in height, how much must the *phalupalu* increase so that the rain water still falls at the same distance from the wall?

- Did you notice that this task has incomplete data?
- What do you need to know in order to solve this task?
- How could you solve this task in case of having complete data?

Tasks like this can be solved in groups of students or individually, as home work, so that the students have time to think without pressure of time, and then the task can be discussed in the classroom.

Note that by midday's sun one can see on the floor of a not yet thatched *round house roof battens' shadow forming* ***concentric circles****. The common centre of the circles coincides with the base of the* ***nzati****. That can be used as an example of concentric circles from the real life.*

One can suggest a task in which one can calculate the surface of a conical roof -- *nsukuli* -- varying the height of the cone and maintaining the radius of the cone base. One can indicate h for the height of the cone, r for the radius of the base circle, α for the rounded inclinations angle of the roof, and S for the surface area of the roof, in the table below:

h	***r***	***tgα***	***α***	***S*** **(= Πrs)**
$\frac{1}{2}r$	r	0.5	27°	$\Pi r\,(\frac{\sqrt{5}}{2}\,r) = 1{,}12\,\Pi r^2$
$\frac{2}{3}r$	r	0.666	34°	$\Pi r\,(\frac{\sqrt{13}}{3}\,r) = 1{,}2\,\Pi r^2$
r	r	1.000	45°	$\Pi r\,(\sqrt{2}\,r) = 1{,}4\,\Pi r^2$
$\frac{4}{3}r$	r	1.333	53°	$\Pi r\,(\frac{5}{3}\,r) = 1{,}67\,\Pi r^2$
$\frac{3}{2}r$	r	1.500	56°	$\Pi r\,(\frac{\sqrt{13}}{2}\,r) = 1{,}8\,\Pi r^2$
$2r$	r	2.000	64°	$\Pi r\,(\sqrt{5}\,r) = 2{,}24\,\Pi r^2$
$\frac{5}{2}r$	r	2.500	68°	$\Pi r\,(\frac{\sqrt{29}}{2}\,r) = 2{,}69\Pi r^2$

Note that the surface or lateral area of a right circular cone is Πrs, where r is the radius of the base and s is the slant height, i.e., the distance from the edge of the base to the vertex.

The students can be asked to construct the graph showing the relation between the roof height and the roof area and then to analyze the graph's monotony. One can link the conclusions of this analysis to the necessary amount of material for roof construction.

Depending on the available means -- scientific calculator or computer programs like "MatLab" and "Cabri" -- the students can have a better idea about the function's graph of the roof area.

Depending on the school level *differential calculus* can be used for deeper study on the graph's behavior, for example, if the graph has or has not a *point of inflection* and how to interpret the meaning of the point of inflection in practical terms for the house builder.

9.1.3 Playing with heaps of oranges

Some heaps of oranges are similar to roofs of types *nsukuli* and *góngwè.* (See figure 6.44 in the section 6.4.3.).

Working in practice, with concrete “equal sized” oranges, the researcher measured the angles between the edges and the horizontal plane and also between the faces and the horizontal plane, and he came to the following conclusions:

- For triangular pyramid: * edge: ≈ 56°
  * face: ≈ 66°

- For square pyramid and *góngwè*: * edge: ≈ 45°
  * face: ≈ 55°

Theoretically the students can replace the oranges with spheres of equal radius and calculate the elements which the researcher has measured and compared. Unfortunately, it is not possible to form a rectangular (not squared) pyramid with oranges. It could be very interesting to verify how many oranges fit into a rectangular pyramid -- *nhamagóngwè* -- and into a *góngwè* of equal rectangular base and equal height and then to compare their formula for the volume.

- What could be the relation between the angles of 45° and 55°, and the most used angles for the roof inclination in houses of a given zone?

9.1.4 Volume of a roof

An interesting task can be the calculation of the *gongwe*'s volume. One knows that the house builder doesn't need to know the volume of a roof but, for the students it can be very interesting to "discover" the difference between the calculation of the *nhamagongwe*'s (pyramid's) volume and the calculation of the volume of roof *gongwe*, with the same base and equal height (See plans in the figures 9.2 and 9.3.).

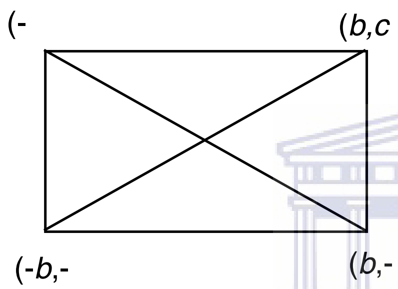


Fig. 9.2: *Nhamagóngwè*

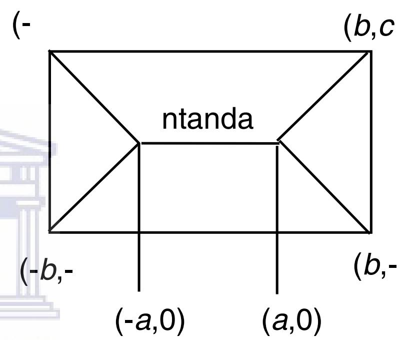


Fig. 9.3: *Góngwè*

One possibility is to start by looking at *góngwè* as a prism in which two pieces are cut out (Fig. 9.4). Notice that *góngwè* is not a truncated pyramid and is not a standard solid.

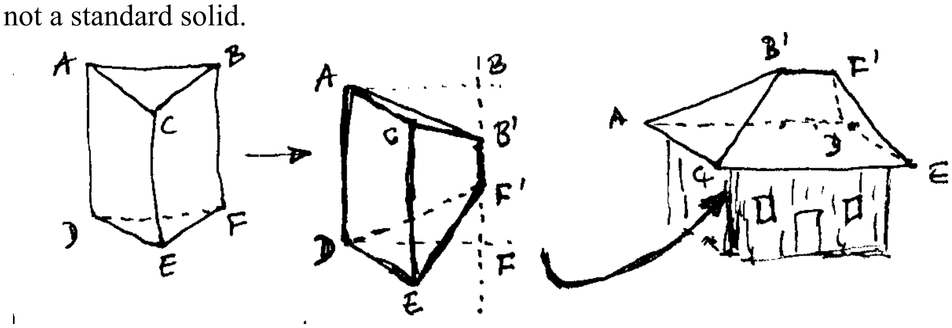


Fig. 9.4: Geometrical transformation from right triangular prism to *góngwè*

From this viewpoint one can say that the "cut out" pieces are two "small" pyramids with the triangular bases ABC and DEF and the apices B' and F', respectively. Given that the "cut out" pieces are tetrahedrons, each of the remaining three faces of each piece could also be taken as bases for the "small" pyramids.

Coming back to the figures 9.2 and 9.3 with these ideas, one can now calculate the volume of the pyramid as following:

$$V_p = \frac{1}{3}\ Sh = \frac{1}{3}(2b.2c)\ d = \frac{4}{3}bcd \qquad (S = \text{area of the base; } h = \text{height} = d)$$

$$\boxed{\text{So, } V_p = \frac{4}{3}bcd}$$

and the volume of the *góngwè* as follows:

$$V_g = V_{prism} - 2V_{small\ pyramid}$$

$$= \frac{2cd}{2}2b - 2\left(\frac{1}{3}Sh\right)$$

$$= 2bcd - \frac{2}{3}\left(\frac{2cd}{2}(b - a)\right) = 2bcd - \frac{2bcd}{3} - \frac{2acd}{3} =$$

$$= 2cd\left(\frac{3b - b + a}{3}\right) = 2cd\left(\frac{2b + a}{3}\right) =$$

$$\boxed{V_g = \frac{4}{3}\ bcd + \frac{2}{3}acd}$$

$$\boxed{\text{So, } V_g = V_p + \frac{2}{3}acd}$$

- How can you interpret the last formula? What does $\frac{2}{3}acd$ mean?
- Now look to the plan on the figure 9.5, where the height in the points (0,0) and $(2a,0)$ is $h = d$.

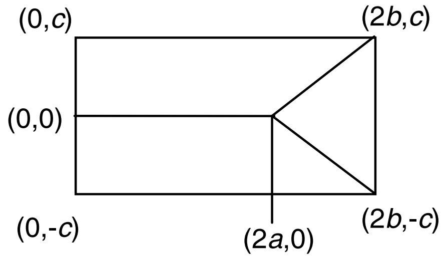


Fig. 9.5

- Calculate the volume and compare with the volume of a pyramid with the same base and the same height.

These tasks have the objective to teach pupils to calculate volumes of non-standard solids. From familiar formula of volumes they determine formula for the volume of "new" solids. In this way they apply their knowledge to new situations.

9.1.5 Exploring mathematically the roof of *góngwè* type

Góngwè is the novelty of the study in terms of geometrical solids.

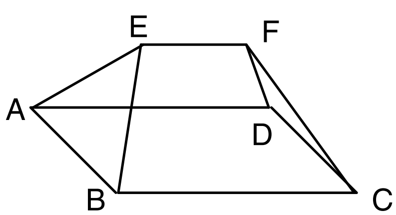


Fig. 9.6

Given the sketch of a roof of *góngwè* type, with following data:

[ABCD] is a rectangle; AB = a; BC = b;

CF = DF = AE = BE = c and EF = d.

EF < BC

Determine the following:

1. angle CBE;
2. angle between the face ABE and the horizontal plane [ABCD];
3. the length of the line segment BF;
4. the altitudes of the triangle ABE related to the base AB and to the base BE;

5. the length of the height h of the roof;
6. the length of the batten joining the mid-points of BE and CF;
7. the length of the line segment between the mid-point of AB and the apex F.

The teacher can ask the pupils to invent and to solve some interesting tasks. Note that one can use vector algebra placing the sketch of *góngwé* in a three dimension coordinate system, using the unit vectors $\vec{i}$, $\vec{j}$ and $\vec{k}$. One can place the origin of the coordinate system in one of the vertices of the base [ABCD] or in the central point of the same base. The innovation in these tasks is that solids like *góngwè* are used as opposed, in a positive cense, to the use of solids like cubes and right parallelepiped.

9.1.6 Box patterns -- plane and space geometry

Pupils can be asked to draw, cut and fold to make boxes: cubic, cylindric, pyramidal, conic, *góngwè*, etc. with open or closed base (see figures 9.7 and 9.8).

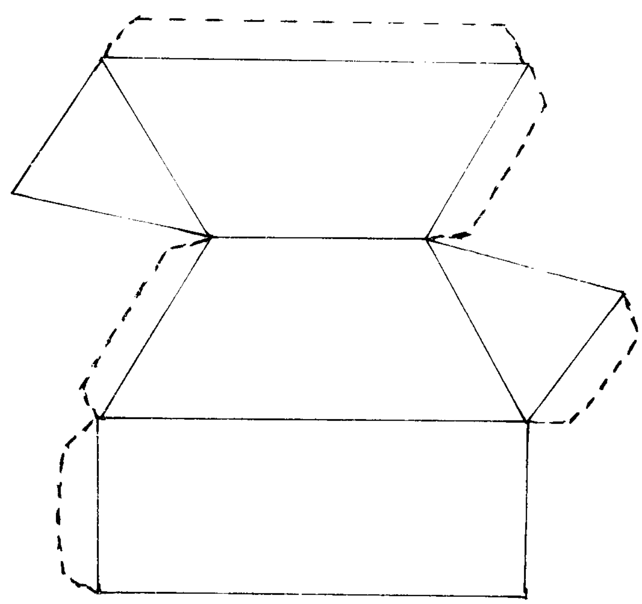


Fig. 9.7: *Góngwè* pattern for box with closed base

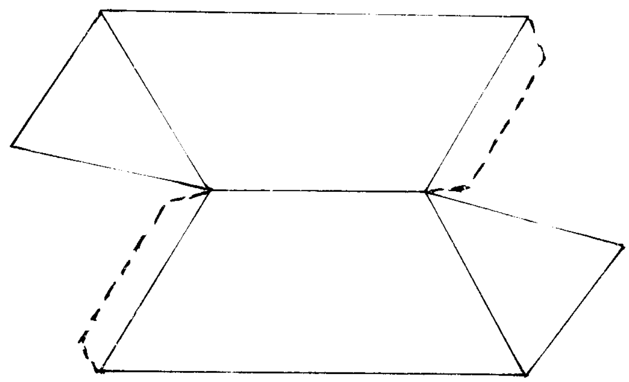


Fig. 9.8: *Góngwè* pattern for box with open base

After constructing the boxes it could be easy for the pupils to recognize that, for example, the angle between the edges CF and DE and the horizontal plane, and between the faces CBF and [DCFE] and the horizontal plane are different. (Fig. 9.9).

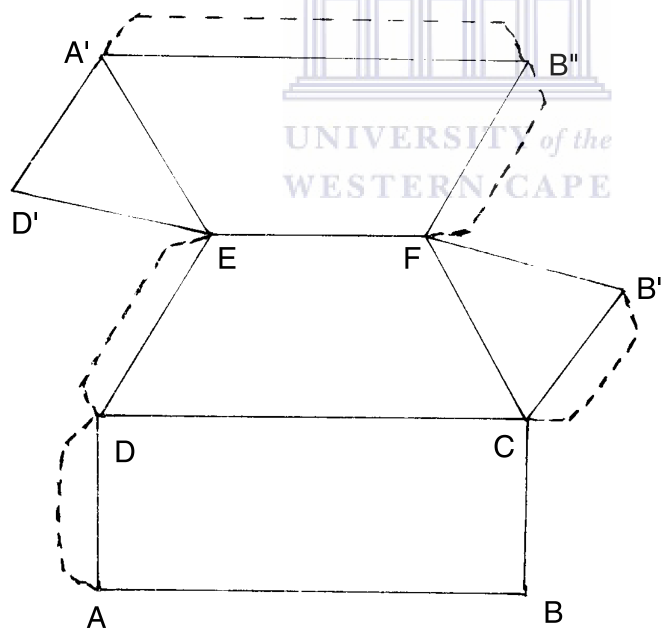


Fig. 9.9: *Góngwè* pattern for box with closed base and point names

After constructing the boxes one can also go back to the tasks in section 9.1.5 and compare the answers with what can be visualized in the boxes.

9.1.7 Circles on the plane and in space

This task can be done by students who at least know that the circle can be represented by $x^2 + y^2 = r^2$. Then, looking at the figure 9.10, in which the two circles represent battens (*kassa*s) from roof *nsukuli*, we can ask a lot of questions.

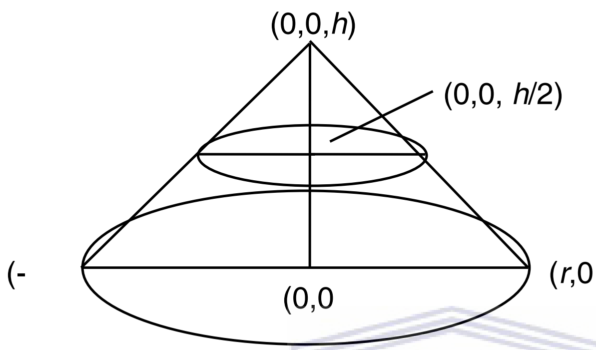


Fig. 9.10

- Write the equation of each circle.
- Calculate the area of each corresponding circle.
- Calculate the surface area between the two circumferences.
- Calculate the surface area of the cone. (Notice that the surface area of the cone can be compared with the area of a roof of *nsukuli* type.
- Calculate the volume between the two circles. (Notice that now one is dealing with a truncated cone).
- Which is the ratio between the length or perimeter of these circles? Compare with the ratio between the areas. What do you notice? Comment on this!

One of the objectives of this task is that the students realize the relation between the ratio in line lengths and the ratio in corresponding areas.

9.1.8 Putting a post in a vertical position

One can ask a question lake this:

- The house builder puts a house post in a vertical position using no instruments to ensure the verticality of the post. Find the mathematical knowledge involved in that job?

This task can be done in the area of Analytical Geometry.

9.1.9 The thinner the *kokotelo*, the bigger is the wall area to be covered

In this section, a demonstration of this statement made by a house builder on the 14th April 1999 (see section 8.9) will be made.

Look at the figures 9.11a and 9.11b, where one can see sketches of *kokotelo* with different cross-sections. It can be clearly seen that with big cross-sections, there are 5 columns and with small cross-sections there are 9 columns.

So, *kokotelo* with big cross-sections can cover an area with a length of 5h, whereas the *kokotelo* with small cross-sections can cover an area with a length of 9h.

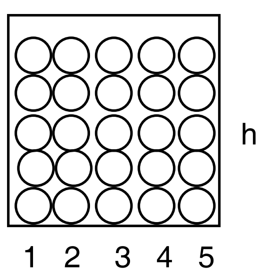


Fig. 9.11a

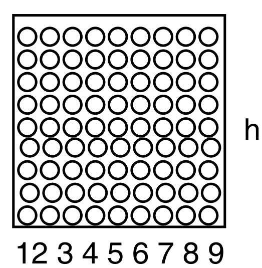


Fig. 9.11b

- It can be clearly seen that the statement of the house builder was mathematically correct.
- What can happen when the *kokotelo* sections are triangular (maybe equilateral

triangles)?

This last task can be more interesting to discuss with students, even if *kokotelo* with triangular section doesn't exist.

9.1.10 Polynomials

According to Larson and Hostetler (1993, p. 34) "… a polynomial is the most common type of mathematical model used to represent real-world situations". The following tasks were suggested based on the above assertion.

1. Copy the following pattern inspired on two-sided roof *(ramada)*. Cut it out and fold it to a prism and then calculate the surface area of the prism.

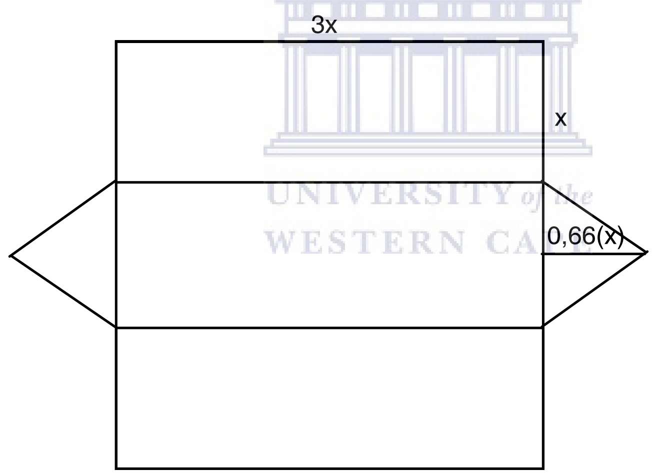


Fig. 9.12

2. One can give the radius and wall height of a round house and ask for the surface area of the wall. One can also give the thickness of the wall and then ask for the internal area of the house wall.
   This is an unusual task in calculation of areas, but has the advantage that it is inspired from a real life situation, that is familiar to many of the students.

3. Look at the next figure (Fig. 9.13). Look that the shaded area, that can

represent the surface area of a rectangular house walls, can be represented by $54x - 8x^2$.

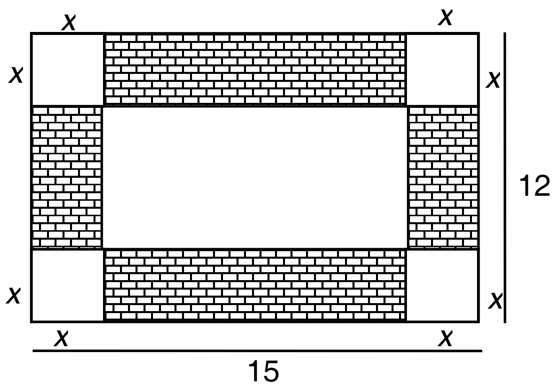


Fig. 9.13

4. Imagine that one cuts out squares from a rectangular piece to make an open box. The edge of each cut-out square measures x. What is the volume of the box? (Fig. 9.13).

These two last questions are tasks involving polynomials. The study of polynomials is one of the most important subjects at secondary school level. Thus, the researcher suggested these two tasks inspired by house building and standard tasks at the same time.

5. The Figure 9.14 represents walls of a traditional house. Known that traditional houses have no foundations calculate the volume of the walls given that the house has no windows, has a wall height of $\frac{x}{4}$, is 20 cm thick, and has a door of 175cm per 110 cm.

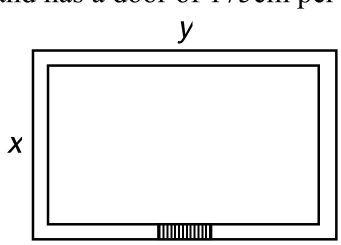


Fig. 9.14

- Show that the external surface area of the wall is $\frac{1}{2}x^2 + \frac{1}{2}xy$ -- 19250.
- Show that the volume of the wall is $10x^2 + 10xy - 400x - 38500$.

- Notice that the volume can be calculated differently. Show how.
- Notice that one can transform the former polynomial in x and y into a polynomial in x. For example one can define that $y = x+250$ cm. Then, one can give the volume of the wall and ask for the lengths of x and y.

6. Volume of a round house wall:

One can give the measurement of *R*, the radius of the external circle of the round wall. Giving the thickness of the wall one can ask for:

- the wall volume, known that the space occupied by the door and windows can be disregarded;
- the volume of mud necessary for covering the wall, given that the material used for the wall framework constitutes a third part of the total wall volume.

  One can increase the complexity of the task giving the dimensions of the door. *Note that the cross-section of the wall the place occupied by the door is not a rectangle, but part of a (circular) sector*.

9.1.11 Working with sequences

Given the sequence a) 1 2 1 2 1 2 1 2 ..., from fences made of sticks and reed bundles (see section 8.14.1), one can generalize for

$$a_n = \begin{cases} a_n = 1 & \text{for odd } n \\ a_n = 2 & \text{for even } n \end{cases}$$

This sequence can become more interesting when one transforms it into *a)* 1 -1 1 -1 1 -1 1 -1 ..., then one has $a_n = (-1)^{n-1}$.

Examples: $a_1 = (-1)^{1-1} = (-1)^0 = 1$

$a_2 = (-1)^{2-1} = (-1)^1 = -1$

$a_3 = (-1)^{3-1} = (-1)^2 = 1$

$a_4 = (-1)^{4-1} = (-1)^3 = -1$

The same formula can be used for the sequence *g)* from section 8.14.1.

Next consider the sequence b) 1 2 1 2 2 1 2 1 2 2 2 2 1 2.

A closer look at this sequence brings out an interesting pattern, viz., 1 2 1 2 2 1 2 1 2 2 2 1 2 (1 2 2 2 2)?...

• What could happen if the sequence were not limited?

A student teacher who had knowledge of this sequence proposed:

1 2 1 2 2 1 2 1 2 ... Thus, $b_n = \begin{cases} 1 & \text{for odd } n \\ 2 & \text{for even } n \ (1 \le n \le 4) \end{cases}$

and

$$b_n = \begin{cases} 2 & \text{for odd } n \\ 1 & \text{for even } n \ (5 \le n \le 9) \end{cases}.$$

As one can see, these are very exciting sequences, not pre-worked ones, whereas the sequences in most text books are first "experimented" with and most often do not present a real challenge. One has to use memorized skills. Consequently, one does not think much when solving problems with them. Students should actively experience new situations.

One can use the sequences *a)* and *g)* for introducing the notion of the *binary* number system. In these sequences there are only two choices for the elements, namely 1 and -1. To have a binary system one has to keep the 1 and to transform the -1 into 0. So, the sequence *a)* becomes: 1 0 1 0 1 0 1 0

In fact:

1 corresponds to **1** reed bundle in the fence;

10 corresponds to **2** reed bundles in the fence.

Unfortunately, 101, that corresponds to 3 reed bundles in the fence, in the *binary system* **101** corresponds to **5** in the *decimal system*. So the 3 bundles correspond to the number of positions. In this case the *binary number* 101 has three positions. In any case this sequence can be useful for explaining the meaning of a positional number system, in this case the *binary system.*

As mentioned at the beginning of this chapter, the researcher's aim was to identify the mathematics, specially the geometry, involved in the traditional house building (in the provinces of Sofala and Zambézia) and to suggest how this mathematics can be used in mathematics education -- presenting some non-routine tasks. The teachers will determine and decide in which grades similar mathematical tasks can be dealt with.

Given that the teacher is not a house builder, more and concrete problems related to traditional house building could be chosen and solved by both students and teachers. So, as Borba writes, “Each partner is going to be learning from the other in a dialectical way.” (Borba, 1997, p. 267). The researcher thus agrees with this point of view.

9.1.12 Two specific tasks for the primary school level

In this section two tasks specific for the primary school that are related to traditional house building are presented.

1. Chande, a young boy, is looking at a house wall. He counts from outside twelve *mbalilo* (battens) lines.

   How many mbalilo lines has the wall altogether?

   This task has to do with the first steps in learning of correspondence and also in multiplication by two -- each mbalilo line on the outside corresponds to one mbalilo line in the internal side of the wall.
2. A roof of a square based house has 7 rafters *(phalupalu)* as a face. How many rafters does the whole roof have?

   This task is apparently trivial, but it can be very interestingly analyzed in bilingual perspective within Echuwabu and Cisena context.

- *In Portuguese and for the Cisena speaking people we have*

  (7x4)-4 = 24

- *The Chuwabu speaking people distinguish among the rafters, palu-palu and mendo -- mendo are the four rafters that form the roof edges. So, if a face has* 7 phalu-phalu *for the Sena, it has* 5 palu-palu *for the Chuwabu.*
  Thus, if a roof face has 7 rafters, for the Sena the roof has altogether 24 phalu-phalu, but for the Chuwabu it has (7-2)x4 = 20 *palu-palu.*

9.2 School projects

One could suggest and organize some school projects as the following:

1. Determine the roof type that is the most used in a certain region and then,

- find out the justifications given by the house owners and by the house builders for the choice;
- compare the former justifications with the justifications that can be gained from interdisciplinary studies, which can include, for example, mathematics (surface of the roof), geography (climate, vegetation) and physics (stability).

2. Determine the most used bases shape for houses of a given region.

- Find out the justifications given by the house owners and by the house builders for the base's choice.
- Compare the found justifications with those gained through a geometrical study.

3. For example, for roof of the *góngwè* type one could consider the following steps:

Being given: • length of the large wall = $2b$

• length of the short wall = $2c$

• variables: * length of the *ntanda* = $2a$

* hight of the roof from beam up = d

Roof plan:

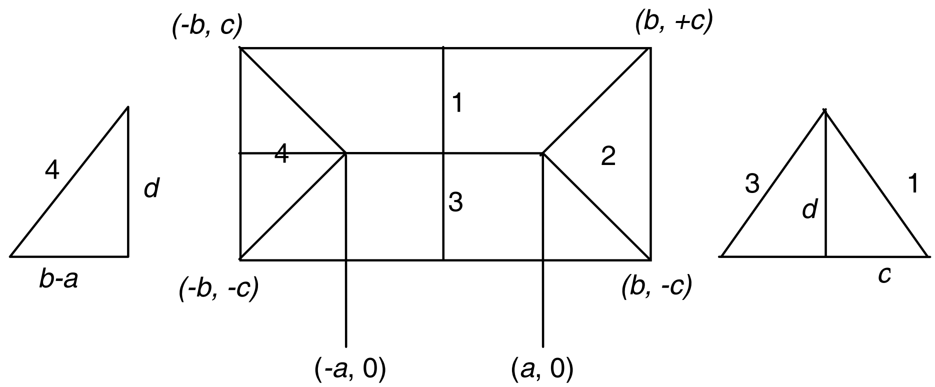


Fig. 9.15: plan of the *góngwè* roof

Roof area: trapezium 1: area $= \frac{2b + 2a}{2} \cdot$ height $= (b + a)\sqrt{c^2 + d^2}$

triangle 4: area $= \frac{2c \cdot \sqrt{(b-a)^2 + d^2}}{2} = c\sqrt{(b-a)^2 + d^2}$

Knowing that the trapezia 1 and 3 are equal and the triangles 4 and 2 are also equal, one will have:

Roof area: A $= 2(b + a)\sqrt{c^2 + d^2} + 2\,c\sqrt{(b-a)^2 + d^2}$ (1)

Using parameters for the "inclinations" of the roof, which determine the speed with which the rain water will run out from the roof, one will have:

One supposes that the inclination of the faces 1 and 3 is: $m = \frac{d}{c}$

One supposes that the inclination of the faces 4 and 2 is: $k = \frac{d}{b-a}$

Ratio between these inclinations: $\alpha = \frac{k}{m} \rightarrow k = \alpha m.$ (2)

• Notice that this ratio varies between $\frac{c}{b}$ (if $a = 0$) and ∞ (if $a = b$). (3)

The *ntanda* length can be kept constant while the roof height is changed, or vice versa. Both parameters can also be changed. From the above variations one can calculate in each situation the roof area, faces' inclinations and then analyze the stability of the roof.

Tasks like this can be solved in groups of students or individually, as home work, so that the students have time to think through them without any time pressure.

After a discussion of the results in the class-room, a comparison phase can be included whereby the the justifications given by the house builders and house owners are compared in more detail.

4. Two Projects on Statistics:

The following projects can be organized with pupils or students of different school levels.

a) A group of pupils can make a survey in a rural village and then produce a statistics table with the number of each house type existing in that village. The data can be organized in tables and/or in diagrams;

b) Are the house types dependant on the region where they are built? Students can choose 3 or 4 rural villages in different regions of the same province -- for example, on the coast, in inland, in the savannah near the sea, etc -- and count the number of each of houses type in each chosen village. Using chi-squared tables and test one can ask about dependence or independence between region and house type. (Here one can give more importance to roof types for the house classifications.)

5. Exercises on elementary Graph Theory (vertices, edges graph and degree of a vertex)

Given that Mozambican children construct toys for themselves using wire and elastic band, the mathematics teacher can tell them to construct roof frames models using wire and elastic band (see figures 9.6 for roof of *góngwè* type) for roofs of *góngwè*, *nhamagóngwè* and *nsukuli* types. One can use the models and their projections on a plane (see figure 9,3) to introduce to the pupils the notions of vertices, edges and degree in Graph Theory.

With these tasks the researcher hopes to have done a contribution for a linkage between academic mathematics and spontaneous, non-standard and folk mathematics, used by the house builders, and even linkage to the mathematics hidden or frozen in the activity and in the final product of traditional house building, i.e., a linkage between *academic mathematics* and *folk mathematics*. So there are tasks in the field of ethnomathematics, linking matematics, culture and mathematics education.

In the next chapter one will present some conclusions of the study and some recommendations.

10. Conclusions and Recommendations

This is the final chapter of the thesis and this chapter the researcher will present some conclusions and some recommendations, not only related to mathematics and mathematics education but other related areas. This is to enable the results of this study to be used by others and also so that that the research can be continued or extended to other (Mozambican) regions. The conclusions are derived from the literature and from the study done by the researcher, observing and interviewing house builders. The conclusions are researchers conclusions derived from his research, his data, sustained by ideas of other authors.

10.1. Conclusions

In this section the researcher will present some conclusions of the study, sometimes comparing or confronting these conclusions with ideas of other authors.

(1)It is clearly evident that the builders, both from Sofala and Zambézia Provinces, make effort to get the beams really horizontal and the posts vertically placed. This means that even if imitating others, the builder knows *what* and *how* to do it. In agreement with Gerdes, it is certain that the first builders to use (or to invent) these methods and all the others who transmitted their knowledge to new builders, were applying the methods consciously. This is because the current builders are capable of explaining *why* it must be done in a certain way and not otherwise.

One is facing spontaneous mathematics as well as folk mathematics. As Gerdes says:

> The artisan who imitates a known production technique is -- generally -- doing some mathematics. The artisans who discovered the technique, *did* quite a lot of mathematics, *developed* mathematics, were *thinking* mathematically. (Gerdes, 1995a, p. 29).

For the researcher, the fact that these processes were not explicitly documented does not detract from their value or reality. It is quite a shocking reality in Africa, and so in Mozambique, that many procedures and popular knowledge are not documented. But, the researcher has to agree with Moriarty, when this author writes that

> It should be clear that in Tanzania *and elsewhere in tropical Africa* there are both well-constructed and poorly-constructed dwellings built from traditional materials. It would be a mistake to condemn traditional housing as inadequate for meeting minimum shelter needs from observations in slum areas of cities, just as it would be mistaken to condemn modern materials and construction methods by observing only slums in the West. ... It is the well-constructed houses which demonstrate the potential for using the *traditional* materials and associated *skills*. (Moriarty, 1980, p. 288 - *Italic* by the researcher.).

But, one has also to consider that

> “knowledge, language and values are not only taken over from former members, they are also used and applied in new situations, developed and transformed, and used again, that is not only reproduced, also produced”. (Mellin-Olsen, 1986, p. 101).

So, in this concrete case, the researcher can say that some house builders who are applying algorithms are thinking geometrically, that they are not applying them blindly, but they develop and transform them positively.

(2) The house builder needs to have integrated (at least empirical) knowledge in:

* mathematics (geometry);
* biology (resistance and flexibility of certain woods, straw type);
* geology (conditions of the soil -- question of termites and ground water);
* geography (climate);
* physics (static -- conditions of balance).

This conclusion can be reinforced with words by Zaslavsky, when she writes that “the African adapts his home admirably to his means of subsistence, *to the available materials, and to the requirements of the climate*". (Zaslavsky, 1999, p. 155 -- *italic by the researcher*.).

Remember that the study shows that, for example the inclination of the house roofs depends on the region.

(3) Frobenius writes that the house type with a rectangular base was introduced to Eastern Africa -- where Mozambique lies -- through the maasai people from the north. (Frobenius, 1894, pp. 49-52).

To that effect the researcher asks: Can the non-European and non-Asiatic names -- *nkhope ya kolo* and *nsana wa ndzou* -- given to houses of one- and two-sided roofs in Cisena, *with rectangular base*, not be proof that the Africans developed the rectangular base without non-African influence? So the researcher agrees with Frobenius that the rectangular base was not imported from outside Africa.

(4) In many African regions one finds a lack of continuity in the evolution of traditional house building (cf., Frobenius, 1894). The researcher agrees with this statement, for example, the earlier ones used to build stone houses over centuries in Mozambique (cf., Elleh, 1996, p. 191). The researcher’s understanding for this situation is that it has its justification in the colonialization, given that the

colonialists tried to banish the native's culture.

(5) The traditional house roofs by the year 1900 were more inclined than nowadays. Why? (See figure 8.11).

This could be because of the fact that the houses nowadays have greater base area so that it cannot be practical to construct roofs with very acute angles? The greater base is a consequence of the furniture used in current days and the family size.

(6) The possibilities to incorporate geometrical elements related to traditional house building in mathematics education in school in Mozambique are given, then, the new primary school curriculum introduced from 2004 reserves ca. 20% of the time for syllabus related to local reality and one found enough examples of mathematical aspects related to traditional house building that can be used in mathematics education. Some of these examples were mentioned in chapters 8 and 9. Creative teachers can formulate new tasks related to traditional house building and other cultural activities according to their reality and their pupil's experiences.

(7) The mathematics involved in traditional house building can be incorporated in the category of *folk mathematics.* Then it develops into a working activity, in this case by building houses. As Bishop writes, "Mathematics in this context is therefore conceived of as cultural *product*, which has developed as a result of various activities." (Bishop, 1988b, p. 182).

At the same time it can be seen as *oral mathematics*, given that part of the methods are transmitted orally from one generation to the next; nothing is written down.

(8) Traditional houses are in general *ugly* represented in the studied

mathematics text books. This can miss-value the cultural and technical importance of traditional houses thus degrading cultural dignity.

(9) The study shows that Africans build round houses not only as a question of facility, or urgency to erect a shelter without professional assistance, as said by some authors. One is reminded of the fact that even the nomadic people, people with *lack of time*, erected shelters with rectangular bases, Fig. 4.1, chapter 4 -- see Frobenius (1894, pp. 21-23 and pp. 38-43) or Elleh (1997, p. 24). In the case of Mozambique, -- Sofala Province -- the way in which the house builders try hard to get the base and top of “cylindrical” walls circular, showed one that they are interested in perfection when constructing round houses (and in this case perfection requires time). Besides, the construction of conical roof, *nsukuli*, is not an “easy” task and it does not save time in any way (see chapter 7).

(10) Using the classification by Andersen (1977, p. 35) one can say that the traditional houses in Zambézia and Sofala are of two types:

1. *Composed of rigid elements* -- the square and rectangular houses;
2. *Composed of rigid and flexible elements* -- the *rigid elements* in houses of circular base are, for example, the posts and the rafters, and the *flexible elements* are the beams and the battens.

(11) The traditional house building is only learnt by observation and *active* participation. As Denyer writes, in the past

> ...construction skills were passed down from every member of one generation to every member of the next since few houses outlasted a single lifetime. This must have been a major exercise in frequently non-literate societies. (Denyer, 1978, p. 92).

But, nowadays, at least in Sofala and Zambézia, the traditional house building becomes a profession and the construction skills are now passed down from a generation to the next generation of the same family or to an apprentice of another family. One can see the example of Quizito Pedro Simaportar (QPS) in the interview from 17.11.2000 (Interview Sofala-3, in Appendix A):

Interviewer (a student): — How did you learn to build houses?

QPS: — I learnt to build houses by helping and observing my father constructing our houses when I was still a child. When I needed to construct my own house suitable for young people — *guero* — I built myself and my father taught me the most difficult parts, such as roof *(nsoi).*

....

Interviewer: — Where did your father learn these methods of building houses, …?

QPS: — Probably from his father.

So one learns to built houses through active participation.

(12) The master builders of traditional houses from Zambézia Province are more demanding than those from Sofala Province when they consider an apprentice to be prepared to be a house builder. One can see that in almost all interviews presented in the appendix. To illustrate this conclusion one gives two examples. Asked about "How could you teach anybody to build a house and how long could he/she take to learn?", Domingos Vinte Mafunga, from Sofala (see Interview Sofala-1, in Appendix A) answered: *"As I said at the beginning, learning to build a house is not a very difficult task as one can imagine. It's an easy task. The secret is that the learner must have interest and the will to learn. In that situation* ***one day can be sufficient*** *to learn everything that is related to house building."* Whereas Sebastião António, from Zambézia Province but, now living in Beira -- Sofala (see Interview Sofala-4, in Appendix A), answered: *"Depends on the person. If he follows me for* ***ca. three months*** *it can be enough. But it depends on the competence of the learner."*

(13) Unschooled traditional house builders can “calculate” the necessary quantities of building materials for each house size. This statement can be compared with the one found in the literature. Quoting Gay & Cole [1976], Carraher et al. (1985, p. 21) referred to a study that “showed that unschooled Kpelle traders estimate quantities of rice far better than educated Americans managed to”.

One is before folk mathematics, mathematics developed in the working activity, through the practice.

(14) Apart from other functions, wall rafters *(mbalilo or balilo)* are placed horizontally in order that they can hold the mud used to cover the walls, especially while it is still wet.

(15) Given that wall posts are placed relatively close to one another, the *optimal solution* to place the *kokotelo* (battens -- thin sticks placed vertically between wall posts) could not be other but the vertical, so that the space between posts of a wall could become well filled. (See Fig. 8.16.)

(16) Knowing that by placing the beam on a house with circular base, the top of the cylindrical wall can become a smaller or a bigger circle than the circle of the base or even an ellipse, the house builder from Sofala Province discovered that to avoid this situation, one has to construct two *makassa* (one internal and one external) on the ground, close to the posts base and then to *transfer* them to the top.

(17) In order to avoid that two faces of the roof from *nhamagóngwè* type decay before the other two faces, given the difference of the inclinations of the faces, both the house builders from Zambézia and Sofala Provinces developed the roof of *góngwè* type, so that the four sides of the roof have nearly the same inclination, if not the same inclination. Note that the house builders from

Zambézia Province construct roofs of *góngwè* type, even if they don't call it *góngwè.* (See table 6.1) That can be seen as knowledge illustration.

If one wants the four faces of the roof *góngwè* to have the same inclination, one needs to construct a *góngwè* in which one has the ratio:
ntanda's length = (base's length) - (base's width).

The construction of roof of *magóngwè* or *góngwè* type has the main objective of removing the inclination differences between the four roof faces.

(18) The leveling of the ground before constructing the house base can show that the house builders, in Sofala and Zambézia Provinces, know that it is not easy to construct a "perfect" geometrical shape, like circle or rectangle, on ground that is not level.

(19) The second method (section 6.1.2b) and the fourth method (section 6.1.2d) for rectangle construction can develop the misconception that a quadrilateral with four equal long sides (that can be a rhombus) is a square, given that the angles are determined by eye, in an intuitive manner.

(20) The methods of placing the posts are related to three-dimensional space geometry. The post (line) is perpendicular to the plane of the ground if it (the post or line) is perpendicular to at least two straight lines in this plane. -- It can be said that the house builder doesn't know exactly how to justify his/her procedures, but they are proceeding correctly by placing posts in vertical position.

(21) Even if they do it unconsciously, the study shows one that the traditional house builder in the two provinces uses direction vectors to put a post in a vertical position to the ground.

(22) 3rd, 4th and 5th grade pupils, and even children who never went to school, know the necessary conditions for a stick to be upright (vertical) in the ground

(see interviews with 4 school children, from March 2001, in Appendix C), but university level students sometimes are not able to write these conditions, according to the researcher's experience with students, because they deal with formula of vector algebra (theoretically) and miss the practical imagination of the situation. For these university students it seems to be a very difficult problem, given the lack of connections between the theory and the practice, where it is possible. Here one has a clear example of what D'Ambrosio called *psychological blockade.*

(23) The incorporation of the mathematics related to *traditional house building* in mathematics education can have the advantage that house building is, in rural Zambézia and rural Sofala, one of the major social occasions in which both men and women (and even boys and girls) cooperate. Plastering and covering the walls with mud are often done by women and children, whereas the construction of the walls, roofs and thatching are made by men, sometimes helped by boys. So, the traditional house building is a "gender free" (independent from gender) activity. Thus, anyone will have something to say in a mathematics lesson where the teacher deals with mathematics related to house building.

(24) In the rural primary schools one can have introductory or revision classes about rectangle, triangle and circle, outside the classroom. Thus, pupils can point to, from the environment, examples for *circle* (house base), *rectangle* (house base, walls, faces of roof *ramada* or *nkhope ya kolo*) and *triangle* (faces of roof of *nhamagóngwè or nsukuli types*). The teacher can ask the pupils to tell him how the adults or themselves construct rectangles and circles for the house base. Then the teacher can compare them (the methods) with the methods used at school or together with the pupils can indicate the geometrical properties which constitute the background of each construction method.

(25) By dealing with plane geometry looking at house walls, house bases and roof faces, the pupil can develop the idea that, when one speaks about plane in the classroom, one must not only think of the black board, or the table top, or of the mathematics text book’s and mathematics exercise book’s sheets.

(26) The process of house building includes a practice that is very important in geometry, namely *omatikela* (see section 6.3), that means to put something on the top of something else -- very important in the first stages of learning of geometry, by comparing surfaces of plane figures, without calculating the areas, for example, through cut and stick or cover.

(27) The method used by the house builder to construct the circle is more directly connected to the definition of circle and circumference used in Mozambique and, therefore, it is more understandable for beginners studying geometry, thus the use of pair of compasses can be learned later.

(28) Some geometrical applications in Cisena and Echuwabu, such as rotation and translation, are represented by verbs (see table 8.1, chapter 8). That can be seen as a confirmation of a statement by Gerdes (1995a, p. 29) that there exists a relationship between geometrical thinking and material production, i.e., that geometrical ideas have their origin in the human practice, in the human activities, then, for the researcher, verbs are linked to movements, to actions or to activities.

(29) The way in which the Sena relate (right circular) cone to right squared pyramid, *nsukuli*, can facilitate pupils to understand one of the methods used for the calculation of the lateral surface area of a cone as a calculation of the lateral surface of a right pyramid with an infinite number of faces.

(30) Ordinary people’s knowledge can be used to enrich mathematics education. For example, the construction of a rectangle applying reflection symmetry to a

right triangle. (see figs 8.6a and 8.6b in section 8.4.1.2.1.)

(31) House building incorporates estimation. For example, house builder determines the size of the house base only by being told by the prospective owner how many divisions the house may have, or how many people the family has, etc., and, only by looking to the walls the house builder can estimate the necessary volume of mud for covering (*omatika*) the walls.

(32) Mozambican teachers and future teachers know or recognize that the origin of the geometry is in the practice (see section 8.4.1.2.3, in chapter 8, answers to question 7) and that can facilitate the incorporation of mathematics related to socio-cultural aspects, to traditional house building in particular, in mathematics education in Mozambique.

(33) In a similar way in which one -- indirectly -- learns to build houses, first as a helper, then as an apprentice and then becoming a master, using ethnomathematics one could learn mathematics from younger ages, through gradual mathematics learning starting with fun/games related to the age, for example, constructing toys. Such as filling surfaces with small plain pieces (notion of area) or filling boxes with small cubes (notion of volume).

(34) The mathematics that can be derived from traditional house building is not only related to geometry. One can, for example, also deal with sequences, polynomials, and statistics, as showed in chapters 8 and 9.

10.2. Recommendations

In this section the researcher will present some recommendations related to the study, but not all of them related to mathematics and mathematics education.

Some of the recommendations are related to traditional house building itself.

The researcher would like to start by quoting Denyer, who writes that

(i) “Should the traditional styles be allowed to decay? This is of course a question which can only be answered by each community of people concerned.” (Denyer, 1978, p. 193).

The researcher thinks that the people, of Mozambique, should not allow traditional house building to decay, for, on the one hand it is a people’s cultural heritage and on the other hand, many people will need, perhaps for decades to come, the traditionally built houses to satisfy their housing needs.

Quoting Denyer again:

> But surely the spirit of making buildings sufficiently flexible so that they can be adapted to meet the needs of each generation of inhabitants can never be wrong at any time or in any place? (Denyer, 1978, p. 193).

In that sense the Faculty of Architecture of the Eduardo Mondlane University in coordination with the Faculty of Anthropology of different Mozambican Universities and other Faculties must do a study in order to, in the end, be able to recommend the “best” traditional houses (prototypes) to be built in each region of the country. For example, one doesn’t know why the cyclone “Delfina” caused the destruction of many traditional houses in Nampula Province, whereas in northern Inhambane and southern Sofala traditional houses resisted the cyclone “Japhet”, (see section 7.3, in chapter 7). This provides baseline information on which further research can be done.

(ii) The researcher has the plan to take this study forward to another phase, maybe in collaboration with anthropologists, physicists, architects, geographers, demographers and environmentalists, where more elements of the social sciences can be researched and incorporated in the work. So he agrees with Denyer (1978) when this author writes that

> The study of vernacular architecture demands an interdisciplinary approach. This makes it exciting, but one of its inherent drawbacks is that it is inevitable that things will be said with which specialists in individual disciplines will take issue. (Denyer, 1978, p. 2).

The researcher is aware of the drawbacks, but he thinks that an interdisciplinary approach is worthwhile.

(iii) More socio-cultural aspects and production techniques related not only to mathematics but also to other sciences must be investigated and then used, so that, at least in the first school years, pupils can work in the classroom with concrete examples of their daily lives and culture and not only with examples from the (standard) text books. Related to mathematics, Gerdes writes that "*'Ethnomathematics'* also looks for other *culture elements and activities*, that may serve as a *starting point* for doing and **elaborating mathematics** in the classroom." (Gerdes, 1995b, p. 12 -- **Bold** by the researcher.).

(iv) The last suggestion reinforces the idea that Mozambique must insist, specially in Mathematics Education, on the necessity that each teacher becomes an educational researcher, at least in his/her classroom. As D'Ambrosio writes, research can be regarded as the link between theory and practice. (D'Ambrosio, 1998, p. 80).

(v) One must do a study about the environmental impact of the traditional house building, given that this kind of construction uses forest resources -- disseminate and preserve the "positive" methods of environmental protection used by the local communities and teach them new methods.

(vi) One would suggest that the mathematics related to traditional house building could be incorporated in mathematics and teacher education for, as some participants of the workshop said, *many times there is a disparity between what is taught, how it is taught and that what the students know*. Another participant said that ***the return to the origins*** (with reference to the practical activities) *can facilitate, in the first school grades, the process of teaching and learning geometry*. The student teachers can make this connection between the theory and the practice in their future work in the classroom. For example, given that the methods used by the house builders to construct rectangles are geometrically correct, they can be used in mathematics lessons.

(vii) In the mathematics text book of grade 3 one introduces circle drawing on paper using borders of cylindrical cans.

The researcher would suggest that one introduces the drawing of a circle using two sticks and a rope, then the pupils can easily see the so-called "same distance" in the definition of circle. After that the teacher can explain to the pupils that on the exercise book one has less space, so that one cannot use sticks and rope to draw circles. Thus, one developed an instrument called compass to draw circles on paper -- one can choose a size for the circle to be drawn and so the distance between the tips of the pair of compasses remains the same until the circle is drawn.

According to the researcher, only in higher grades can one work first with the theory and then look for its practical applications, where it is possible. However, one should not forget to work with practical tasks and then look if it fits in the theory.

(viii) Mathematically seen, a study similar to this one must be done in the other Mozambican Provinces in order to find out which mathematics and mathematical ideas are involved in traditional house building in different regions and to compare them. Very interesting would be the comparison using the local languages: for example the relation of inclusion between square and rectangle in different local languages. The Chuwabu house builders, for example, include rectangles in squares, whereas the academic or school mathematics includes squares in rectangles.

(ix) In classes of Adults' Education one can deal with issues related to traditional house building of different regions of the country, so that the adults who are house builders can exchange ideas and knowledge, in order to improve their work.

As Knijnik (1997) writes,

> When a specific subordinate group becomes conscious of the economic, social and political disadvantages which its scarce knowledge brings about, and tries to learn erudite knowledge, this type of consciousness may contribute to the process of social change. (Knijnik, 1997, p. 409).

(x) Coming back to the recommendation that more socio-cultural aspects and production techniques related not only to mathematics but also to other sciences must be investigated and then used at school, one needs to say that "a lot" of work in that direction was already done (and is still being done) by, for example, Paulus Gerdes.

(xi) However, given the vastness of Mozambique, and the socio-cultural and ethnic diversity, much more work can and must still be done.

(xii) Many house builders use knots in ropes to join sticks. So, the researcher suggests that knots could be studied and their results used in Topology.

(xii) The Beira branch of the Universidade Pedagógica in coordination with the Provincial Government of Sofala (Educational Authorities) should provide conditions so that the *SofMat -- Encontro de Professores de **Mat**emática de **Sof**ala* [Meeting of **Mat**hematics Teachers of **Sof**ala] could be restarted as a regular meeting of mathematics' teachers of Sofala from senior primary school upwards, with two main objectives: (*) to establish a regular contact among the mathematics teachers of the province in order to discuss issues related to difficulties teachers face in the process of teaching and learning Mathematics; (**) to promote, together, strategies for the improvement of mathematics teaching in the Province. *SofMat* could be a "noble opportunity" to disseminate *ethnomatematical ideas* among the mathematics teachers of the Sofala Province.

The *SofMat* experience should be extended to other sciences and to other provinces in order to improve teaching and learning of science and mathematics in Mozambique.

The researcher hopes to have contributed so, that many people look differently (positively) to traditional houses and to the process of traditional house building.

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APPENDICES

Some raw data.

Appendix A: Some interview transcriptions (10 interviews)

Appendix B: Example of a field note (One page)

Appendix C: Inquiry guides from ARPAC-SOFALA (Cultural Heritage Archive) on traditional dwellings and villages

Appendix D: Children's knowledge of verticality in space (interview transcriptions)

Appendix A

Some interview transcriptions

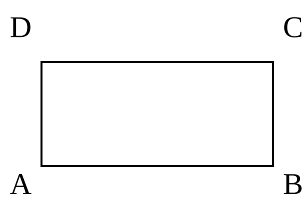
In this section the researcher will present the transcription of interviews with house builders from Zambezia and Sofala Provinces (done in Echuwabu and Cisena, respectively).

First one will present the used interview guide.

INTERVIEW GUIDE

(The questions 5, 6, 7, 12 and 15 are only valid for houses of rectangular base)

1. What is your name? *(If possible:* How old are you?*)*
2. Who built the house where you live?
3. How did you learn to build houses?
4. *(Keeping in a bag various sticks with at least four having the same length, in two different sizes and a line)* How do you arrange or prepare the base of a house?
5. *(If necessary)* How do you ensure that the base is exactly like you intended to do?
6. *(In case of using a line to measure the diagonals)* How are you going to straighten the base if you notice that a distance measured by a line, for example AC, is longer than the other, BD?



7. How do you know that this method brings in “perfect” shape for the base?
8. Do you know any other method to prepare the base of a house?

   (Let him/her describe the method, ask him/her why does he/she not use it.)

9. *(In case the builder once joined school.)* Did you go to school, have you learnt these method(s) at school?
10. From where the person who taught you this method and to build houses, in general, was learning?
11. After doing the base, it's sure that the following step is to place pillars. How do you ensure that a pillar is well placed?
12. How do you differentiate, in your mother tongue, a base with all four sides equal from a base with two opposite sides equal, but not all four sides equal?
13. What inclination have you used for the roof?
14. To what extent does the roof inclination influence the fact that a house drops or not?
15. What position or guidance follow the houses you build? What guidance follow the houses, in general?
16. If you were living close to a mountain or near to the beach, what guidance could follow the houses.
17. How did you learn to build a house?
18. How did you know that you could build a house, yourself (personally)?
19. What kind of tools do you use? Are there any other tools that you miss for your job?
20. How could you teach anybody to build a house and how long could he/she take to learn?
21. In building walls, some builders use lines or rope to tie up the sticks and others use nails. What material do you use, nails or lines, and why?
22. In what stages do you divide the building of a house?
23. What is the most difficult stage?
24. If the house builder is describing a building process of a house with circular base, additional questions must be asked:

24.1 How do you mark the positions for the posts?

24.2 When the roof is made outside the wall frame, how do you determine the size of the roof?

24.3 When the house has two walls, how do you determine where each wall passes, on the ground?

24.4 When you are placing the beam, how you know that the wall both at the top and at the bottom will have the same size?

25. (The interviewer must try to obtain in a builder’s language words or expressions that refer to:)

1. angle
2. vertical
3. horizontal
4. oblique
5. ranged
6. middle
7. center
8. apex or corner
9. straight
10. curved
11. diagonal
12. rotation
13. translation, etc.

1. Interview Zambezia-1

Interview with Sualé Isaac Sualé (Maquival, 05/07/97)

Interviewer: Daniel Soares

(I revisited this house builder in March 14, 1999)

In this interview I began with a short presentation of what I pretended and then continued as follows.

Daniel: — I know that you are constructing these two not-yet-finished houses and that you have already constructed many others. I would like that you simulate how you prepare the base for a house.

Sualé: — I need four sticks with the same length or four sticks, equal two by two. My house *(one of the two houses in construction is for himself)* has a square base and the house for my sister has a rectangular base *(He used the Portuguese terms for square and rectangle.)*.

Daniel: — I have here four sticks each two equal. While you are thinking how to explain to me, I will quickly go to cut four equal sticks (equal in length).

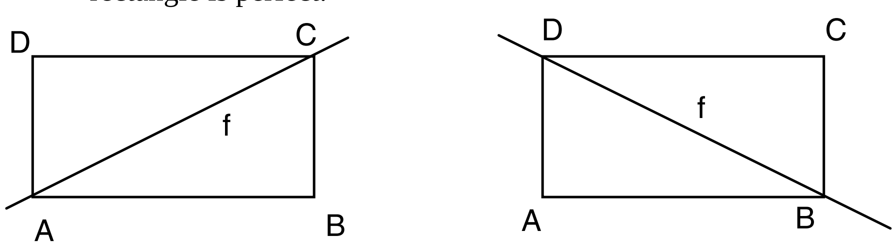
Sualé: — I place the sticks like that *(with the sticks he forms an apparently perfect rectangle)* and thus I have the base for a house formed.

Daniel: — How can you ensure that this base is perfect, that it is a rectangle?

Sualé: — For that I will need a rope or string.

Daniel: — What will you do with the rope.

Sualé: — Two people take the rope, one at each end. We stretch the rope (f) between two opposite corners of the base of the house, measure the distance and compare with the distance between the other two corners. If the two distances are not equal, then we adjust the sticks and measure again. When the two distances become equal, the rectangle is perfect.



Daniel: — How you proceed if the base is a square?

Sualé: — The procedure is the same that I have previously described.

Daniel: — How do you know that this method brings in perfect rectangles and squares?

Sualé: — I have learnt it from my father, and have observed many famous house builders using this method.

Daniel: — Do you know another method?

Sualé: — No, I know only this one.

Daniel: — You have attended school. Have you by chance learnt this method at school?

Sualé: — I completed grade 7 and couldn't continue studying. This method that I am using I have also learnt at school, maybe in the grades 4 or 5.

Daniel: — Your father didn't attend school. Where have your father learnt this method? *(I knew that his father didn't attend school.)*

Sualé: — I cannot explain but, when I learnt this method from him I have never imagined that I could one day learn the same method at school too.

Daniel: — After doing the base, it is sure that the following step is to place pillars. How do you ensure that a pillar is well placed?

Sualé: — What gives more job is the placement of the four corner pillars or posts. The other posts become "well upright" by placing the beams. *(In Echuwabu: ripa; pl.: ripa = beams).*

To put a post upright I place it in the hole, previously opened in the ground, and I stand at a certain distance. From there I look to the base and to the top of the post several times. Thus I see if in that direction the post is upright or not. After that I change my position in order to see if in this new position the post is upright or not. If the post is upright in this two positions, then there are no problems — the post is well placed, well upright and can be *fixed* in the hole in that position. I do that with the four corner posts of the house.

At this point some house builders make mistakes.

Many of them place the posts well but make mistakes when they place the beams.

Sometimes, when one is placing the beams some posts are exposed to a deviation. Some house builders are not aware of that or they don't care about that.

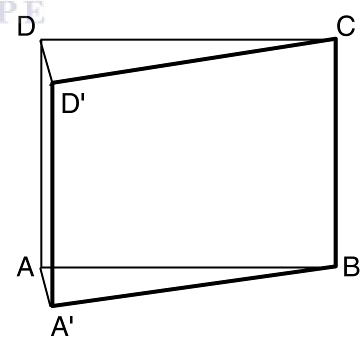
After placing the beams it can occur that they don't form a rectangle or a square, that means that some posts are inclined, which can cause the future house to fall. In this case one says that the house is twisted *(orintea)*.

Another situation that can occur is that the top suffers a deviation but stil keeping the square or the rectangular shape. However, the house is also inclined *(otedemana)* and can fall down or can not be (beautiful) perfect.

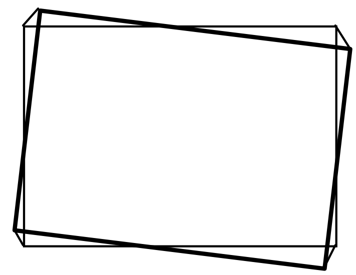
a) *Orintea* — to be twisted

On the plan the posts DD' and AA' are inclined. The rectangle formed by the beams was exposed to *orintea*. It is like the points D and A turned round the points C and B, respectively, by the same angle.

Plan



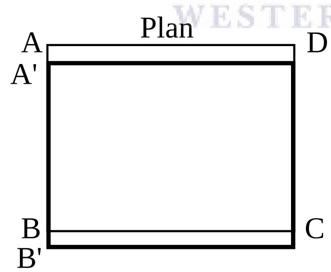
Plan

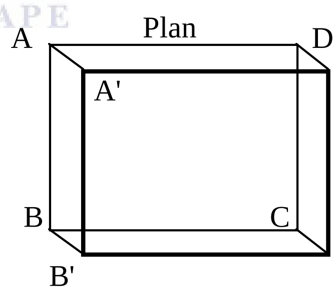


On this plan one can see that the structure of the house suffered *orintea.* It is like the rectangle formed by the beams rotated round the cross-point of the diagonals. This defect is sometimes combined with a translation.

b) *Otedemana* — to be inclined

This defect is characterized by the fact that during the placement of the beams the house is forced to an inclination in the direction of one of the walls or in the direction of one of the diagonals from the base or in addition these two situations combined, however maintaining the rectangular or square formed from the four beams. (See the plans below.)





(AA', BB', CC' and DD' are posts and bold lines are beams)

When this mistake (*otedemana*) occur the house builders say that the house is *not beautiful (otakala)* or that the house *is falling (egwa).* They use the term *otedemana* only when they want to explain what it means if a house to be *otakala* or *egua.* Depending on the grade of the inclination a house which is *otedemana* can even so be concluded and one can live in it.

So, after placing the beams a reliable house builder verifies once more the structure of the house in order to check if the house is in the vertical position and provides all actions so that it can be, before placing the roof.

Daniel: — How can you differentiate in Echuwabu a house with rectangular to a house with square base?

Sualé: — Now I cannot remember. I use the same terms as in Portuguese — *rectângulo* and *quadrado*.

(I told him the terms in Emakhuwa — according to José Calisto da Rocha — in order to help him to remember the terms in Echuwabu but he couldn't remember. José Calisto da Rocha *is my student in the LEMEP course - Masters in Mathematics Education for the Primary School)*

Daniel: — What inclination do you often use for the roof?

Sualé: — Depends on the house. Small inclination doesn't work and very big inclination does not look well. But the most inclined for me is generally a difference of seven hand spans from the level of the house's beams. Not from the level of the beams of the verandahs, if the house has verandahs.

Daniel: — To what extent does the roof inclination influence the fact that a house drops or not?

Sualé: — Depends on the height of the *mutana* or *muamba*. When the *muamba* is very short small "pools" are formed on the roof due to crooked *paru-paru*. When the *muamba* is high one cannot notice the effects of crooked *paru-paru*. Even if the thatching is rotten the roof can remain useful, given that the rain water doesn't stay on the roof.

(Muamba — the structure or stick that supports the roof and marks the difference between the apex of the roof and the height of the walls

in a house of four-sided roofs.)

Daniel: — What position or orientation do the houses you build follow?

Sualé: — It depends on the house's owner. The position can take into account the direction of the main street or trail, which passes near the house. But in general the houses are so built that the back door looks to the sea (to the Ocean). Even if an important road passes near the sea, between the sea and the house, the back door will look to the sea and to the road.

(I noticed and confirmed that in all houses that I observed in Zambézia Province with the exception of three, from three young men, one of them married.)

Daniel: — How can one learn to build houses?

Sualé: — I learnt by observing my father and helping him by house building. When he measured the distances between opposite corners was I held the rope at the other end. Sometimes I put the end in the wrong position and he corrected me. At the time I didn't understand the role of the rope. Thus I was learning.

Daniel: — How did you know that you could build a house, yourself (personally)?

Sualé: — I experienced myself and adults, some of them famous house builders, observed and told me that the house was well erected. Some adults do not agree that I built that house. It was a house for my younger brother and myself.

Afterwards I built another house for my mother *(at that time the father was dead)* and people began to recognize me. Now I have built 6 houses. I received invitations to build houses in the villages of Colongone and Mudenga *(nearly 10 and 5 Km from Maquival(Mochoro), respectively)*. One thing that I learnt alone is that one doesn't need to be a carpenter to become a competent house builder or that one doesn't need to have lots of tools in order to built a perfect house. I have only a panel saw *(sarrote)*, a hummer *(martelo)* and a *semo.* However there are house builders who even so need a square *(quadra)*, a spirit level *(oniva)* and *prumo.*

But I think that it is easier and quicker to form the base of a house using a rope than using a square. Also it is very easy and quick to check the verticality of the posts and the horizontality of the beams by one's eye, taking some positions, than using *prumo* and *oniva*, respectively.

Daniel: — How could you teach anybody to build a house and how long would he/she take to learn?

Sualé: — I would invite that person to help me building a house. The first thing to teach him would be to form the base of a house and then to put the posts upright. The remaining steps would depend on one's intellect, his/her curiosity and his/her attention.

Daniel: — You use mainly rope and strings to join sticks but in Quelimane *(in the townships of Quelimane city)* one uses more nails.

Sualé: — That depends more on the possibilities. If I had more financial possibilities I could maybe use more nails and wood.

About the resistance I don't know if it is a big difference but I know that in the conditions in which I build houses, it becomes cheaper, even if it probably takes more time to finish the job.

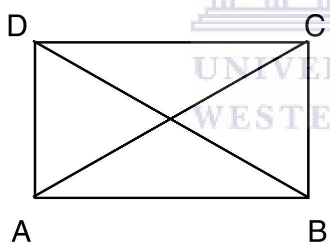
Daniel: — Some house builders prefer the use of a square to determine the base of the house but you prefer the use of rope. Is it because you don't have a square?

Sualé: — Even if I had a square I would continue to use rope. Is a very quick procedure to determine the square or the rectangle. With the square one needs to “go” through the four corners several times until one put right. *(He defends his method as the best one.)*

With rope you can put right in an instant and when you take a square you can confirm that the angles are correct. *(The first time that he speaks about angles in the whole interview and uses the name in Portuguese “ângulo”. Two Years later (14.04.1999) he changed his mind about the use of square to confirm the equality of the base angles.)*

Daniel: — Imagine that you are using the method that I can call “of the diagonals” and in the measurements you notice that AC is bigger than BD. *(See the figure below — the quadrilateral [ABCD] was represented on the ground through 4 sticks.)* How could you proceed to put it right?

Sualé:



If AC is bigger, then I will push from here into interior *(indicating the vertex C)* so that the corner A doesn’t move.

I measure again. If this time BD is bigger, then I push from B or from D into interior leaving the corners D or B fixed, respectively.

I repeat this procedure until the two measurements, AC and BD become equal.

Some geometrical terms (English — *Echuwabu*)

angle - komo *(there are only known angles smaller then 180°)*

vertcal - yowimela

oblique - yotedemana

ranged - yowalinharea or yowalinyarea

middle - vari *(very general term that can also mean center)* vertex - tompa

corner - komo

curved - yokuruvari; yokoromana *(crooked)*

transversal - yoguaguanha or yoguaguanya

rotation - ozugunuwa *(can ols mean turn round)*

2. Interview Zambezia-2

Interview with Zeca Amisse (Mochoro, 07/07/97)

Zeca is 13 years old, passed to grade 5 but in this year, 1997, is not attending school.

Interviewer: Daniel Soares

After presentation the interview began.

Daniel: — How did you learn to build houses.

Zeca: — Nobody taught me really to construct houses. I was observing my uncle building houses and helped him, there in Magologodo, where we were living. What I did in this house that you are seeing was to reproduce what I saw my uncle doing.

Daniel: — *(Presenting various sticks with at least four of equal length in two different sizes.)* How do you form the base for a house?

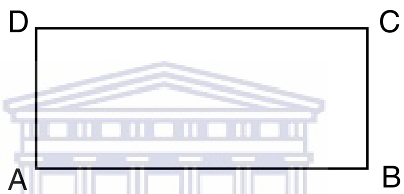
Zeca: — I pinned four sticks in the four corners of the future house. For each wall length I measured one *armful* and one half. Then I took a very long rope and passed it around the four corner sticks as you are seeing. *(He simulated using a rope and four small sticks - from that I have presented at the begin - pinned in the ground. Then he took more small sticks to pin in the places where posts will be placed. Two sticks are separated more, to indicate the place where the door will be placed. One* ***armful*** *is the distance between a fingertip of a hand and the opposite shoulder.)*

— After that I have indicated the places for the posts. I remove all sticks and begin to dig holes where the posts will be placed.

Daniel: — How do you ensure that this base is perfect?

Zeca: — For that I will need another rope or string. I do the measurements and if the distances between vertices are different I change the position of some sticks *(He points to opposite vertices).* At that moment I have to remove the first rope from around the corner sticks and then place it again. Then I put again the other sticks indicating the posts' places.

Daniel: — How will you correct the base if you by measuring with the rope notice that, for example, AC is longer or shorter then BD?



Zeca: *(He gave a confused explanation. He is not sure about the how to proceed but, he knows when the rectangle or the square is well determined.)*

Daniel: — How do you know that this method results in perfect rectangles and squares?

Zeca: — I saw my uncle doing like that and I think that he was right.

Daniel: — Do you know another method to construct a house base?

(Leave him to describe and then ask why he doesn't use it.)

Zeca: — No, I didn't know.

Daniel: — You have attended school. Have you by chance learnt this method at school too?

Zeca: — No, I cannot remember to have learnt this method..

Daniel: — How did your uncle learn to construct houses?

Zeca: — I don't know how and from whom he learned.

Daniel: — Is your uncle a carpenter?

Zeca: — No he is not a carpenter. But I saw him building many houses.

Daniel: — You said that your house has one *armful* and half each side. How did you measure that on the ground?

Zeca: — I took a rope and measured on it one and half *armful*. Then I took this rope and cut a straight stick with this length. Using this stick I constructed a square on the ground. Thus

1. I lie the stick on the ground and mark here and there. *(He marks the ends of the stick on the ground,)*
2. *(He adjusts one end of the stick on one of the marks and forms nearly a right angle with the former position of the stick and says:)* Afterwards I put the stick so and mark here. *(He marks on the free end on the ground.)*
3. *(Next he lies the stick in new position, rounding ca. 90° putting one end on the last mark and saying:)* Now I put here and mark there. *(Marks on the free end, on the ground.)*
4. Next I put the stick here. *(Trying to put one stick's end on the last mark and the other end on the first mark. But the stick was longer then the distance between the two marks. — Then he changed the position of the last mark and measured again with the stick.)*
5. *(without saying nothing he puts one end on the first mark and marks on the other end, on the ground.)*
6. Then I lay the stick here, ready, it is finished. *(Saying that he lie the stick between the last and the previous marks. It fitted well and said that it was ready.)*
7. Now I put/pin small sticks in the four corners and pass a long rope as I explained before.
8. Then I pin other small sticks along the rope on the ground along the

four sides indicating the future places for the posts.

9. Next I remove the rope and while I am removing the sticks one by one I will put signals on the ground where I will dig holes for the posts.

   (This time he didn't speak about how he could ensure that the obtained figure on the ground was in fact a square or not.)

Daniel: — After doing the base, it's sure that the following step is to place pillars. How do you ensure that a post is well placed?

Zeca: — (*He couldn't explain well. At the beginning he was thinking that I was referring to* crooked *posts and not to* inclined *posts.)*

Daniel: — How can you differentiate in your mother-tongue a base with four equal sides from a base with two opposite sides equal but not all four equal?

Zeca: — I cannot be sure there are special designations in my mother tongue, Echuwabu. I only say square — *ya quadrado* — and rectangle — *ya rectangulo*.

Daniel: — What inclination do you often use for the roof? To what extent does the roof inclination influence the fact that a house drops or not?

Zeca: — For the roof I had the help of my father. He prepared the *mendo*, put nails still on the ground; prepared the *batente* and the *muamba*.

Daniel: — How can one learn to build houses?

Zeca: — I don't know well, given that I am still learning. I don't know well how to construct a house but I think that it is necessary to work with one who knows well and help him in some tasks.

Daniel: — How did you know that you could build a house, yourself (personally)?

Zeca: — It doesn't mean that I can myself build a house. I only experimented because I have a 15 year old friend who has his own house.

Daniel: — How could you teach anybody to build a house and how long could he/she take to learn?

Zeca: — I am not able to teach someone to build house. I can only find a friend building a house and help him.

(There was no more time to continue the interview with Zeca.)

3. Interview Zambezia-3

Interview with Francisco Manuel Maulate (FM) (Maquival, 16/07/97)

Francisco Maulate is a house builder from Macuse, Namacurra district.

Interviewer: Daniel Soares

Assistant: Madalena Francisco Dovirar (Interviewer's mother)

(I revisited this house builder in March 17, 1999)

Daniel: — I am a person from school, a person from the Education. There exist things which people learn at school so that after learning these people think that only they, who went to school know that. They think that people who did not attend school are ignorant, brute and know nothing.

FM: — Yes ...

Daniel: — What we want is to try to collect more arguments that show that many of the things that are taught at school have their origin in activities of the daily life, at home, and that the difficulty in recognizing that, one finds in the lack of facility in transferring what is done at home, for example, to the written language.

FM: — That is the truth!

Daniel: — A person begins to do something and then reflects about how he did: "Ah, when I do that like this, it becomes so, and when I do it in another manner it becomes like this." When this person is literate, then he writes about what he verified. But, most of the times, by teaching something at school it seems that only you know that and the pupils also think that only the teachers know what they teach and that the people at home know nothing about that. That is not true most of the time. What can happen is that the people at home know the same thing in their own way, at a way different from the way at the school.

Is in that context that I want to speak with people who construct houses, houses like ours (traditional houses) in order to know how they build and how they think, which materials they use and, if possible, which similarities do exist with the brick buildings. It is because of that, that I look for people like you to talk about house building.

First I would like to know your name and how you learnt to build houses.

FM: — My name is Francisco. May I tell you the full name?

Daniel: — I think that it could be better.

FM: — My name is *Francisco Manuel Maulate*.

Daniel: — Yes...

FM: — Learn to build a house. I don't know if you are thinking about preparing the building materials, for example, preparing the post, is it that?

Daniel: — I'm referring to your first learning steps. If you have observed somebody, if have helped and so learning slowly...

FM: — I began observing and learnt that first one cuts a coconut tree, marks the measurements *(length)* of the posts, where one has to take in account that part of the post will be under the ground. The post must have 3,5 meters or 2,5 meters. Then one splits the tree pieces and smoothes the posts.

Daniel: — Yes.

FM: — After that one looks for wood for the beams.

Daniel: — Yes.

FM: — After having the wood for the beams it is also splitted and cleaned. Then all beams are put on the ground in order to verify if they are straight *(not curved)*, to avoid curved walls. Straight work is pleasant.

Daniel: — Yes, is pleasant.

FM: — When one puts a post in the hole one checks also by the eye if it is well upright or not. If the post itself is curved or not.

Daniel: — But, doesn't there exist someone who Mr. Francisco recognizes as the person from whom you learnt to build houses? Or you may have learnt from many persons by looking that from them and this from another person, until you concluded that now you could construct a house?

FM: — Yes. When I am walking on a street/road I look to the old houses. I began this job a long time ago. I see that that house is well built or that it has a fault, that that beam is higher this side, etc. I can stand from far away and see that that house has a fault and that the fault could be corrected this way, for example, that one could push that post to that side.

Daniel: — How long ago did you construct your first house?

FM: — I constructed my first house long time ago, when I was still a young boy. I constructed in my native region, Macuse. I was living there for many years until I began to move to other places. When I came to Maquival I built also a house from where I moved as soon as I asked for this place and constructed the house where I am living now.

Daniel: — How did you know that you were capable to build a house alone, that the observations that you did with house builders were enough to be able to construct a house?

FM: — ... (Silence.)

Daniel: — At that time that you built your first house in Macuse, how did you know that you were capable, were prepared, to construct yourself your own house.

FM: — I knew alone. Maybe given to the fact that I was thinking that after collecting the building materials, if I will have lack of money, then I could construct totally the house, alone. If you have no money, you will invite nobody to help you. You have to do extra effort to conclude the house alone, according to your liking.

Assistant *(Interfering in the interview):* — If the house is well built people will come asking: "Have you yourself constructed? Then you will become a real master?"

Daniel: — I have the impression that you have not understood me well. I would like that you tell me how did you construct your first house. If you have invited people to help or if you have built it alone? ...

FM: — While I was building my first house my brother was there. He helped me by placing the posts. When all posts were in the holes I asked him to push this or that post into this or that direction. I looked, observed and he pushed, straightened.

Daniel: — It was you who were looking?

FM: — Yes. I was looking.

Daniel: — Was you the "master"?

FM: — Yes. I was the master. I was looking and said that now this post is well, is not tilted and can be well fixed in the hole. And so on until we placed the first beam. After the beam was placed I was looking from one end to the other end and saw that both ends were equal, were at the same height. We placed all four beams, my brother and I. During all construction my brother and I were there, in my first house, in the adolescence.

Daniel: — When one constructs a house one can use four equal long beams or two short and two long beams, to determine the base.

FM: — Yes.

Daniel: — I don't know if there exist names that differentiate these two house types? Names that differentiate houses with all four sides equal from the other type which has two opposite sides equal!

FM: — That one that is very long to a side we call it *nyumba ya mapara meli* (two-sided roof)

Daniel: — That is according to roof type. But, what is the name according to the base. Some people call it *nyumba yelapi* (house of length = house of rectangle). Is that correct? When it is like this (pointing to a rectangle drawn on the ground) they say that this house is of *elapi* (of elapi = rectangle, not squared), can one say that?

FM: — Some people say so, that is, each person has his knowledge, has his dialect. Some people know as house of rectangular base (nyumba yelapi), others know as two-sided roof (nyumba ya mapara meli), because a house with two-sided roof has rectangular base.

Daniel: — House with two-sided roof has a rectangular base.

FM: — Yes.

Daniel: — Now, what is the name of this one? *(Pointing to a square drawn on the ground.)*

FM: — The name of this one is house of four-sided roof (nyumba ya mapara manai). House of four-sided roof is the one in which the four sides are equal.

Daniel: — It is ok. ... I have here sticks that imitate beams and that imitate posts. I would like that you simulate here what you said about how one begins to construct a house. I don't know if you will start with a house of rectangular or with a base with four equal sides. These four sticks are equally long but, these two are longer. You can choose.

FM: — Are the beams already conditioned?

Daniel: — Yes.

FM: — *(He took the two long beams and placed them parallel on the ground, at a certain distance one from another.)* I fit this beam here and here *(manipulating a short beam.).*

Daniel: — They have withered. Given to that they cannot fit well. They were all of the same diameter, but I cut when they were still green.

FM: — After fitting this beam here and here *(takes the second short beam and fits it at the free ends of the two beams first placed on the ground)* I have a house of two-sided roof *(house of rectangular not-squared base).* House *yelapi*, as you have said.

Daniel: — It's ok! Now, after forming the beams, how do you know that the base is well arranged? *(to be well arranged means, in this case, to be a rectangle)* How do you see that the base is not so "inclined" *(I moved the base frame and I had a non-rectangular parallelogram.)* Given that the sticks are very small we can see easily that it is not well arranged.

FM: — Yes, with small sticks one can just see.

Daniel: — But, with long sticks it is maybe more difficult to see that it is twisted, that it is not correct. How do you ensure that the base is well arranged?

FM: — To know that it is well, to make that it not so *(He points the parallelogram of sticks on the ground),* after putting the sticks in this position ...

Daniel: — Yes, on the ground ...

FM: — On the ground. Then we take a rope and we do like this. *(He takes a* *small rope and stretches it between two opposite vertices of the parallelogram already formed.)* That one who knows the job doesn't go confused.

Daniel: — I agree.

FM: — After stretching the rope from here up to there, we fix this measure. Then we stretch the rope again from here up to there *(referring to other two opposite vertices)* and it must be the same measure. If one, after placing the beams on the ground, ignores this step, the house can be not beautiful. But, if one does like this and adjusts the beams so that the distances between opposite vertices become equal, one can indicate the places for the posts with the certainty that the house will be pretty. After that one digs the holes for the posts. After placing the posts one places the first and the second beams. Then one places all beams over the posts. Next one stands far away from the house structure and one looks to the beam level and then from top to the bottom and from bottom to the top, in order to determine the right height for the house. If we want a high or a low house the last decision is there. After deciding about the right height for the house, we choose a well placed post and adjust well the others in the holes according to the height of this one.

Daniel: — All right! Now, when you are measuring, when you measure like this, and then measure here *(measuring the parallelogram diagonals)*, if you notice that from here up to there is longer *(pointing one of the diagonals)*, how would you proceed to adjust?

FM: — If I notice that here it is longer? *(Points to the wrong diagonal.)*

Daniel: — The longer part is this.

FM: — If this distance is bigger I have to fix well this part *(points one of the long beams)* and push a little bit this side, like this. *(catches a vertex* *that is not related to the fixed beam and pushes "parallel" to the fixed beam).* Even after pushing one has to measure again here and that side too *(points to the two diagonals).* If the measure is the same, then the base is alright, one can mark the places where posts will be placed.

Daniel: — Well! When you have to put a post like this one upright, so *(I pin a post in miniature in the ground.),* how do you see that it is well upright? *(To be well upright means to be in the vertical position.)*

FM: — In order to see one has to go a little bit far away from the place ...

Daniel: — Yes ...

FM: — From there one can see better if the post is not well upright. If it is the case we tell somebody who is near to push the post into this or that side *(points to the left and to the right)* until it becomes well.

Daniel: — *(Standing up on the opposite side to the side from house builder I catch the small post on the ground, that he said to be well upright and inclined it to the side where I was standing.)* Well, if it is standing so, but being like this, what can you say now?

FM: — It is necessary that I turn to the other side or another person may be on the other side *(points to his left side)* in order to "catch" the view from that side. *(The positions of the builder, the imaginary assistant and the post form a right angle on the ground with the base of the post.)* If you are alone, you cannot stand only on the one side. So you cannot see well. You have to stand up in a position and then turn and stand up in the other position.

Daniel: — Can it be the same person who first takes a position and afterwards the other position?

FM: — Yes, it can be the same person. Takes a position, looks to the top and to the base of the post, changes the place and looks also to the top and to the base of the post. And orders to push the post into a side or other side, if the post is tilted. After that he ensures the post is well placed in that position and orders the post to be well fixed in that position, putting more soil in the hole.

Daniel: — The method that you indicated me to adjust the base of a house is that of using a rope. A person measures so and here so, when the two measures are equal, then the base is well fixed and one can begin to think on the positions for the posts, etc. Do you know any other method to verify if the base is correct without using a rope?

FM: — Other method without using a rope?

Daniel: — Yes.

FM: — Without a rope one can try by eye to see if the base is not longer to that side or to this side, in order to correct. *(He refers to the diagonals' length.)* That, if one cannot have a rope. But, one must have a rope, given that all work must be measured, so that one can work with certainty and the work goes well.

Daniel: — There are people, who use carpenter's square. I don't know if it is a good method!

FM: — In fact, the use of a square is another method and is also a good method. One checks the corners with the square. If the base is long for a side the square doesn't get out *(That means that the square doesn't fit into the angle.)*. If the base is not long on one of the sides *(refers to the diagonals)* the square fits well and it leans well against this side and that side *(refers to the two beams, which form the angle)*, here will too lean well against this side and that other side *(referring the sides of another angle)*, there the same and there also the same thing *(points the remaining two angles of the parallelogram)*. The four corners must accept well the square.

Daniel: — But, as I can see, you like more to work with the rope?

FM: — But, it's all the same to me. If I don't have rope, I can work with square.

Daniel: — But, when you are working, what do you prefer, working with the rope or with the square?

FM: — For me all are important. If I don't have square I work with rope, and if I don't have rope, I can work with square. But, I think that I work most of the time with rope.

Daniel: — Passing to the case of the roof...

FM: — Yes. For erecting the roof?

Daniel: — Yes.

FM: — To erect, for example a four sided roof ...

Daniel: — Yes ...

FM: — ... one measures from here up to there and determines the middle point *(he doubles the rope used to measuring)*. Cuts a little bit the beam to signal the middle point. Then one measures from here up to there and determines the middle point, so that the roof stands on the center. After that, one cuts a new beam and places crossing those beams, that was measured, passing through their middle points. After making a small hole in the middle point of this latest beam, so that the apex of the roof can stand at the center of the house, it is placed over the others. Next one finds a very straight stick *(muamba)*, to erect the roof. One makes an *espiga* on that stick, so that it can fit well in the hole made in the new beam. After fitting the stick over that beam one takes a rope or very long and thin stick. Next one stretches the rope or puts the thin stick extended from the top of the *muamba* up to one of the vertices of the superior structure of the house. So, we can see from the bottom if the roof will have or will not have the desired inclination. If you have a friend, who is helping you, it is better to work with a rope. He stretches the rope while you are observing. If you are alone, then you nail the long thin stick and observe from the bottom. Thus, you can see that, if I erect the roof with this or that height the roof will not drop while it is raining. Even working alone, you can use a rope. You stretch the rope and you brake or stop it with a nail.

Daniel: — Will there be someone on the top to mountain the upright stick *(muamba)* in the vertical position?

FM: — Can be and may not be necessary for someone to stand on the top. If the *espiga* fits well on the new beam, the *muamba* will be well upright. One can even check with a square in order to see if it fits well, to see if it is not inclined. If it is not inclined, then you can stretch the rope and stop it with a nail. You can also help the *muamba* with a stick, so that it doesn't incline by stretching the rope. After that you can start thinking on constructing the roof. You prepare a *batente* and place it on the superior part of the *muamba*, after making also a *espiga* in that end. Then you take a *palupalu* and nail it. You nail the first, the second, the third and the fourth. After that you go inside the house and check if the roof is well upright. If it is not upright, you adjust the *palupalu* and stop the first *palupalu* with nail.

Daniel: — One stops it with a nail or one ties it with a rope?

FM: — With a nail. You check again. If you conclude that it's all ok., then you brake all *palupalu* with nails. Thus, the house is almost ready.

Daniel: — Yes. How can you see from the bottom that with this *muamba* height the roof will have a good inclination and that it will not drop inside the house?

FM: — When you are standing on the ground at a certain distance of the house, you can see well how the roof will be inclined.

Daniel: — With the help of the rope about which you spoke?

FM: — Yes. *(Simulating with a small rope.)* If the rope has this inclination after stretching, the roof of house will drop as a result of the rain.

Daniel: — So it is not good?

FM: — No. If it will not drop then it will not last for a long time. To avoid that, to have a good roof, it must be well inclined, so that, when it rains, the water drains easily to the ground, without dropping into the house.

Daniel: — What is the normal length of this stick *(muamba)*?

FM: — Some make it with one meter and half -- one meter and fifty.

Daniel: — Yes.

FM: — This stick must not be two meters. It can have one meter and fifty or one meter and forty. It depends on the dimensions of the house.

Daniel: — What happens to this stick *(muamba)* if the house is smaller?

FM: — If the house is smaller, say one meter and fifty, this stick can be of one meter and forty or one meter and thirty.

Daniel: — All right! I don't know if you, by constructing a house think about the fact that the sun rises this side, sets that side, the house must face this side, do you think about that?

FM: — Yes, I think about that.

Daniel: — Then, which position does the houses that you build take?

FM: — If the sun rises this side, the door must be always facing that side. *(Points to the south).* However, there are people who construct houses so, that the door faces the sunrise direction, but the most common is that the door faces this side *(points once again to the south)* or to that side *(points to the north).*

(In Macuse the Sea is in the South.)

Daniel: — That means that the normal thing is that the door must face this side *(south)* or that side *(north).*

FM: — Yes. And some houses with two doors have one door facing this side *(sunrise)* and the other door that side *(sunset),* it depends more on the owner. Some build so that the door faces to the sea *(south)* and the other door that side *(north)*, so that the wind from the sea goes through the interior of the house.

Daniel: — But, which side stays the main door.

FM: — Some put the main door on that side *(south, sea side)* but, most of the people put the main door this side *(northern side -- opposite to the sea).*

Daniel: — All right! What kind of tools do you use in your work?

FM: — Work of building houses?

Daniel: — Yes, by building houses.

FM: — By building houses, after preparing the posts, one needs a saw *(sarrote)*, chisel *(escopulo)*, brace *(formão), semo,* and if there is any heavy work one will need *n'tcho* and, sometimes a big *semo.*

Daniel: — Is formão (brace) the tool used to make holes in the beams?

FM: — Yes. Holes where one will fit the *espigas* of the posts.

Daniel: — When one wants to place the small vertical sticks *(kokotelo)*, that will give body to the walls, first one has to tie some sticks horizontally *(balilo)*, crossing the posts, isn't it?

FM: — Yes. When one is going to place *kokotelo*, one must first tie *balilo.* One has first to tie *balilo* in all walls and then one can look for *kokotelo*. After placing *kokotelo* in all walls follows the phase of *closing* — the phase in which one ties *balilo* to inside.

Daniel: — Could you explain me why the *kokotelo* is leaned against the external *balilo* and not to the internal *balilo*?

FM: — It depends. Some people place the *kokotelo* so that they lean against the external *balilo*, others place so that they lean against the internal *balilo*.

Daniel: — But the majority place so that they lean against the external *balilo*. I don't know if it is so.

FM: — Yes, it is.

Daniel: — Do you know why it is so?

FM: — Yes, I know. There are people who lean the *kokotelo* against the external *balilo* and "close" to inside and others who lean the *kokotelo* against the internal *balilo* and "close" to the outside.

Daniel: — When you lean the *kokotelo* against the external *balilo* which answer do you give to people who want to know why you do like that?

FM: — I will say that we are placing the *kokotelo* in a house and that after placing we will "close". I will say that there are people who begin with the external and "close" with the internal and other people, who begin with the internal and "close" with the external.

Daniel: — But, if one comes ordering you to place the *kokotelo* so that they lean against the internal *balilo*, you will refuse, isn't it?

FM: — Refuse to place the *kokotelo* leaning the internal *balilo*?

Daniel: — Yes.

FM: — No. If you see that your friend began placing the internal *balilo*, then you must also place the *kokotelo* to inside. Can it be that he has his reasons to begin so.

Daniel: — All right! When you are planning to construct a house, what is the most difficult phase?

(Silence, that could mean that he did not understood the question.)

Daniel: — I don't know in what phases do you divide the construction of a house. Maybe, it can be the collection of the materials — cutting a coconut tree, divide it, etc — the phase of preparing the base, erecting of the walls, the placement of the roof, ... What phase do you think to be the most difficult?

FM: — The most difficult phase, the phase that gives more job, maybe it can be the thatching of the roof. Because looking for *makubari (coconut palm leaves)* is very difficult. Sometimes one thatches a roof side and the other sides can stay for some days. There are also other phases, that are difficult, but if one wants too see the house ready, one has to make some effort. If one wants to thatch with *nhokas (nhokas are thatching material made of woven coconut tree palm leaves, widely used in the southern seaboard of Zambézia Province)* one has to start weaving some time before until they are sufficient to thatch the house.

Daniel: — Do you know how to do all things related to house building? You know how to cut a coconut palm and to divide it into pieces, to weave *nhokas*, to weave *magadji* for provisional houses *(magadji is a material used to cover walls in provisional houses and annexes made of woven coconut palm leaves), ...*

FM: — No, *magadji* I cannot weave. I never learnt to weave *magadji.*

Daniel: — You never learnt do weave *magadji*?

FM: — No, I never learnt. One must say what one can. When I need *magadji* I ask people who can weave it and I buy it.

Daniel: — Changing a little bit the course. If someone came here asking for learning to build a house, how could you teach him?

FM: — A person who wants learn to build a house?

Daniel: — Yes. He never built a house, never caught a coconut palm, but wants to learn to build a house. How could you teach him? I know that nowadays it is seldom to find children who want learn to build houses. Many of them go to school or sell something in the markets or they do something else. There are not many, who want learn to do rural life activities. In among these all situations a child appears who wants to learn to build houses. If you were his master, how could you teach him?

FM: — All right!. That means that, he never even cut poles?

Daniel: — No. He doesn't know.

FM: — I will say the following: if you want a house, first we have to cut a coconut palm. If he never cut, I will explain to him that the coconut tree is cut so: the tree is cut from bottom — I take an axe and cut down the coconut palm. After the palm is falling down I mark the desired measures for the posts and we cut the palm into pieces. According to the tree's length we can have three to four pieces.

Daniel: — Yes.

FM: — Then I order him to ask for an axe, I take my axe and we start together dividing or splitting one of the pieces. ...

Daniel: — Well, I think that it is all what I had to ask you. Could you accept that I take a picture of you explaining the arrangement of the beams on the ground using a rope like that?

FM: — Yes, I accept. But, ...

Daniel: — All right, you can change your clothes.

4. Interview Zambezia-4

Interview with Mr. Alfazema (Navilembo, 19/04/99)

Observer: Madalena Francisco Dovirar (author's mother)

In this interview I began with a short presentation of what I pretended and then continues it as follows.

Daniel: — My mother told me that you are a house builder with a very prestigious image here and in the other villages. I would like that you simulate how you prepare the base for a house.

Mr. A. — I need four sticks with the same length or four sticks, equal in groups of two but not all four equal. My house has a rectangular base *(He used the Portuguese term for rectangle.)*.

Daniel: — I have here some sticks.

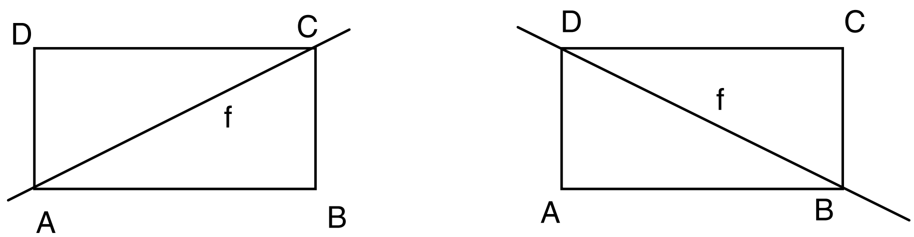
Mr. A.: — *(He selects four sticks equal two by two.)* I place the sticks like that *(with the sticks he forms an apparently perfect rectangle)* and thus I have the base for a house formed.

Daniel: — How can you ensure that this base is perfect, that it is a rectangle?

Mr. A.: — By looking, through experience. If any doubt I can use a rope or string.

Daniel: — What will you do with the rope.

Mr. A.: — Two people take the rope, one in each end. One stretches the rope (f) between two opposite corners of the base of the house, measures the distance and compares with the distance between the other two corners. If the two distances are not equal, then one adjusts the sticks and measures again. When the two distances become equal, then the construction of the rectangle is finished.



Daniel: — How do you proceed if the base is a square?

Mr. A.: — The procedure is the same that I have previously described.

Daniel: — How do you know that this method brings in perfect rectangles and squares?

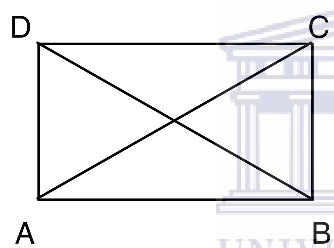
Mr. A.: — I have learnt so from my father, and have observed many famous house builders, like Mr. Chessa, using this method.

Daniel: — Do you know one other method?

Mr. A.: — Yes. I know that one can use a square to check the angles, but I use only this one. Rope one can find everywhere.

Daniel: — Imagine that you are using the method that I can call “of the diagonals” and in the measurements you notice that AC is bigger than BD. *(See the figure below — the quadrilateral [ABCD] was represented on the ground through 4 sticks)* How could you proceed to put it right?

Mr. A.: — If AC is bigger than BD, then I will push from here to there *(indicating from vertex A to the vertex C)* so that the corner C doesn’t move.



Then I will measure again. If this time BD is bigger, then I push from B or from D into interior leaving the corners D or B fixed.

I repeat this procedure until the two measurements, AC and BD become equal.

Daniel: — Have you attended school?

Mr. A.: — No. My school was to build houses and to work on the field.

Daniel: — Your father didn’t attend school. Where have your father learnt this method? *(I knew his father when I was a young boy. To go to school I went past Navilembo Village.)*

Mr. A.: — He learnt from my grandfather and from my uncle, his older brother.

Daniel: — After doing the base, the following step is to place posts. How do you ensure that a post is well placed?

Mr. A.: — To put post well upright I place it in the corresponding hole, previously opened on the ground, and I stand at a certain distance. From there I look to the base and to the top of the post several times. Thus I see if in that direction the post is upright or not. After that I change my position in order to see if in this new position the post is upright or not. If the post is upright in these two positions, then there are no problems — the post is well placed, well upright and can be *fixed* in the hole in that position. One repeats this procedure with the four corner posts of the house.

Daniel: — How can you differentiate in Echuwabu a house with rectangular to a house with square base?

Mr. A.: — Now I cannot remember. I use the same terms as in Portuguese — *rectângulo* and *quadrado*. We are now slowly forgetting some words of our own mother tongue.

Daniel: — What inclination do you often use for the roof?

Mr. A.: — Depends on the house. Small inclination doesn't work and very big inclination doesn't look well.

Daniel: — To what extent does the roof inclination influence the fact that a house drops or not?

Mr. A.: — The secret is the *muamba*. When the *muamba* is very short, it can happen that small "pools" are formed on the roof due to crooked *paru-paru*. When the *muamba* is high one cannot notice the effects of crooked *paru-paru*. Even if the thatching is rotten the roof can remain useful, given that the rain water doesn't stop on the roof. But, when the *muamba* is too high it can be dangerous for the house builder while thatching. He can fall down.

(Muamba is the structure or stick that supports the roof and marks the difference between the apex of the roof and the height of the walls in a house of four-sided roofs.)

Daniel: — What position or direction follow the houses you build?

Mr. A.: — It depends on the house's owner. Generally the position can take into account the direction of the main street or trail, which passes near the house. But in general the houses are built so that the back door looks to the sea (to the Ocean). In our tradition one cannot sleep with the head facing the sea.

Daniel: — How can one learn to build houses?

Mr. A.: — I learnt observing my father and helping him with house building. Sometimes he let me build some parts of the house and corrected me if I was wrong.

Daniel: — How did you know that you could build a house, yourself (personally)?

Mr. A.: — I experimented myself with some young friends, and adults, who observed, told us that the house was well built.

Afterwards I built other houses alone.

Daniel: — How could you teach anybody to build a house and how long could he/she take to learn?

Mr. A.: — I would invite that person to help me by building houses. First he, never she, had to become my apprentice for some weeks or months. It will depend on his competence. The first thing to teach him would be to form the base of a house and then to put the posts upright. The remaining steps would depend on one's intellect, his curiosity, ability and his commitment.

I'm a house builder and carpenter. If he wants to become a carpenter too, then he has to work with me for at least six months.

Daniel: — Why not she?

Mr. A.: — It is seldom to find a girl who can build houses.

Daniel: — You use mainly rope and strings to join sticks but in Quelimane *(in the townships of Quelimane city)* one uses more nails.

Mr. A.: — That depends more on the possibilities. If I had more financial possibilities I could maybe use more nails and sawed wood. But, at other hand nails can go rusty.

Daniel: — Some house builders prefer the use of set square to determine the base of the house but you prefer the use of rope. Is it because you don't have a set square?

Mr. A.: — Even if I had a square I would continue to use rope. As I said before, one can find rope everywhere.

Daniel: — So, it is becoming dark. We can finish our interview now. Thank you for the time and for the lesson.

Mr. A.: — It was a pleasure for me.

5. Interview Sofala-1

Interview with Domingos Vinte Mafunga (Tica-Nhamatanda, 19/11/00)

Interviewer: Alberto Línder (**E**)

Observer or Assistant: Mariano Jaime (**Obs**)

House builder: Domingos Vinte Mafunga (**D**)

E — What is your name?

D — My name is Domingos Vinte Mafunga.

E — How old are you?

D — I am 51 years old and I was born in Mutarara, Tete Province.

E — Who built the house where you live?

D — I built it myself.

E — How did you learn to build houses?

D — I learnt from my father when I was a boy. First my father sent me to fetch building material like grass, rope, reeds and sticks. Then he taught me how to build. Ordered me to dig holes and to construct the walls up to the phase of constructing the roof. I began with the construction of a sleeping annex *(guero).*

E — How do you arrange or prepare the base of a house?

D — I began with digging a hole. But first I had to know the measurement of the wall side that I intended to build. Given that we didn't have measuring tape, we used the arms, stretching the arms many times to the desired length. Got the measurement of a side one prepared four sticks or ropes with the same length. After that I dig ..Sorry! ... pinned two small sticks in each end of a stick or stretched rope on the ground — the measurement of the length. Then I made connections in order to have a squared structure.

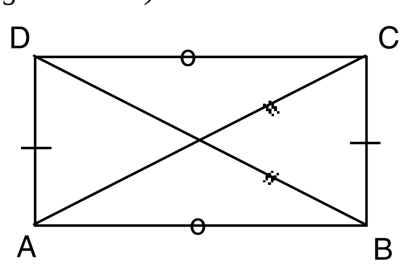
E — How do you ensure that the base is exactly like you intended to do?

Obs: *D takes the small sticks and rope which we gave him on the table and forms a quadrilateral saying:*

D — In order to ensure that this "box" is or is not perfect I use the rope and join these two points *(Obs: — He refers to the diagonal)* and using the same measurement I join the other two points *(Obs: — Referring to the other diagonal)* and, if one of the points, i.e., the pinned small sticks do not coincide with the end of the rope I will try to adjust the sticks or the ropes until the two distances become equal.

E — Mr Domingos is speaking about a "box" with four equal sides. How can you ensure that the base is perfect for the case in which the four sides are not equal?

D — Well, if the sides are not equal, then the base has to be so formed, that the sides are equal two by two. If it is the case, then the procedure in order to check if the base is perfect or not is the same used for the squared "box". *(Obs: — See the figure below.)*



E — How are you going to straighten the base if you notice that a distance measured by a line, for example AC, is longer than the other, BD?

D — If that happens I try to adjust the corners — doing something at the vertices. As said the diagonals have a big role to making real this objective of forming a house base that has four sides — a square or a rectangle.

E — How do you know that this method brings in "perfect" shape for the base of the house (rectangle and square)?

D — I know if the base is squared or rectangular using the method of crossing diagonals which, as I said at the beginning, I learnt from my father. Someone who never saw or never learnt how to build houses can miss this knowledge. Without this knowledge the house can become tilted.

E — Do you know any other method to prepare the base of a house?

D — Apart from the square and the rectangular "boxes" one can make a round "box". Well, if I know how to construct the square and the rectangle using other methods ... I cannot lie. At the moment I only know what I have presented.

E — Did Mr. Domingos go to school?

D — Yes. I studied up to the grade 3.

E — Have you learnt these method(s), that you use for building houses, at school?

D — We did not learn at school how to construct rectangles. We learnt only reading and writing.

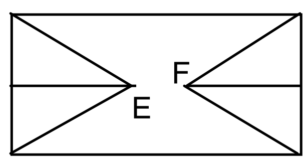
E — Where did your father learn this method and building houses, in general?

D — This thing of building is a thing that is transmitted from a generation to the next generation. In my tradition, the adolescents must not sleep in the same house with the parents. So, when one reaches that phase, the adolescent has to build his own house or annex. And, by trying to construct the annex, that we call “guero”, in my mother tongue, the adolescent tries to learn by the father, uncles, friends or by experienced people about house building. It is enough to construct once. Further one needs only to improve the techniques by building more houses.

E — After doing the base, it's sure that the following step is to place pillars. How do you ensure that a pillar is well placed?

D — The first phase is to build the base. After that, one makes the holes with the same depth. In analogy the posts must have the same length.

Guaranteed of these two particularities, the corner posts are placed in the holes. One puts some sand in the holes for a provisional fixing of the posts in the holes. Then, changing my places I ensure that the posts become upright. After that, using the first posts as reference, I place the other posts of the “box” and fix them definitively. Then I fix the stick of the base center. This stick that we place in the center we call *nzati* in my mother tongue. It has the function to secure the roof-to-be for houses of square base. For the rectangular base we use two sticks for the *nzati*s. (*Obs. — He draws on the ground*. *I -- the observer -- indicated with E and F the places for the two* nzatis.)



E — How do you differentiate, in your mother tongue, a base with all equal sides from a base with equal sides two by two?

D — In my mother tongue the designation of a house depends on the roof type. Thus, the house with square base has a roof of *nsukuli* type. Is a roof with the form of a pyramid of square base. One calls also *nsukuli* the roof built over a house with round base, but this time the roof has the form of a cone. For houses of rectangular “box” the roof is called *nhamagóngwè*, when the length is not very long than the width. *(Obs.— Roof of this type has a shape of a rectangular pyramid).* If the difference between length and width is very big, the roof is from type *ramada*, that is, two-sided roof. Summarizing, we have: nymba ya *nsukuli*, nymba ya *magóngwè* and nymba ya *ramada*. In my mother tongue *nymba* means house.

E — What inclination have you used for the roof?

D — The inclination of the roofs varies according to a builder's pleasure/liking. I have only to say that the more the roof is inclined the better is the ability for the roof not to retain the rain water, that is the guarantee for the lasting of the roof and of the house in general.

E — What inclination ... Sorry! What position or guidance follow the houses you build? What orientation follow the houses, in general?

D — The houses that I build and the houses that I know have, in general the door facing the sunset *(Obs.— opposite to the see)* in order to be on one's guard against heavy rain.

E — How to learn to build a house?

D — One can learn to build a house from someone experienced and indicated for that or assisting someone building a house many times. I can say that it is not very difficult to learn how to build a house. One needs only to pay attention by learning. With a good master one can learn in one day.

E — How did Mr. Domingos know that you could build a house, yourself (personally)?

D — The experience showed me that I was prepared when I have built a *guero (Obs. — correct written is "gero" but, one reads "guero" that means sleeping annex, as said before.)*

E — What kind of tools do you use? Are there any other tools that you miss for your job?

D — We had constructed different types of houses according to the nature of the materials that we use. For houses of type “suit”, those houses with walls and thatching of grass, or with walls with reeds, we need no nails. But, for houses of type *Nhamagóngwè* we need nails for the roof frame. Panel saw is another very important tool for the house building.

E — How could Mr. Domingos teach anybody to build a house and how long could he/she take to learn?

D — As I said at the beginning, learning to build a house is not a very difficult task as one can imagine. It’s an easy task. The secret is that the learner must have interest in and will for learning. In that situation one day can be sufficient to learn everything that is related to house building.

E — By building walls, some builders use lines or rope to tie up the sticks and others use nails. Which material do you use, between nails and lines, and why?

D — The use of more nails or more lines depends on the kind of materials that one is using for the construction. For example, as said before, when the house is of reeds it makes no sense to use nails. But, if the house is made of bamboo it becomes more resistant when one uses nails.

E — In what stages do you divide the building of a house?

D — A house is divided in three phases: forming the base; constructing the walls and constructing the roof. Maybe a fourth phase is covering the walls — with grass or mud — and thatching the roof.

E — What is the most difficult stage?

D — Among the four phases the most difficult, for me, is the construction of the roof. As I said, the roof is the guarantee for the lasting of the whole house. The more the house doesn’t drop the bigger the possibility that the house can last for a long time.

E — Could you tell us in your mother tongue the following terms?

D — Yes!

Some geometrical terms in Cisena:

1. angle = yakulungama;
2. vertical = walumgama (one stick); yalumgama (plural)
3. horizontal = waguangwanyka (sing.); yaguangwanyka (pl.)
4. oblique = wapendama; yapendama (pl.)
5. ranged = walungama; yalungama (pl)
6. middle = pakati na pakati
7. center = pa nzati
8. apex or corner = pa nghomo
9. straight = walungama; yalungama (pl)
10. curved = khona
11. diagonal = ntsana
12. rotation = zungumisa
13. translation = fendeza

E —Do you have something more to say, Mr. Domingos?

D —No. I would like only to say that I liked the manner that you treated me. If you one day come to need something from me you can come. I will not go out from here, from Muda.

E —Thank you! We also liked your hospitality. We will go back to Beira very satisfied. We are very grateful that you accepted our invitation even if it is raining. You should be with your family but, Mr. Domingos accepted our invitation and is here with us. We wish you good health and greetings to your family. See you next time.

Obs —Thus, the interview with Mr. Domingos came to end. It was done in the shop of Mr. Augusto Macopa, near Mr. Domingos' house, given that it was raining a lot outside.

6. Interview Sofala-2

Interview with Elias Mandjona (Mafarinha - Dondo, 18/11/00)

Interviewer: Eugénio Fernandes

Observer or Assistant: José Candrinho

The house builder was born in Marromeu and speaks one of the Cisena dialects, the *phoso*.

1. What is your name?

   My name is Elias Mandjona, and I'm 54 years old.

2. Who built the house where you live?

   Myself.

3. How did you learn to build houses?

   In our time we learnt to build houses when we went to initiation rituals. We had to build the houses where we have to live during that time.

4. How do you arrange or prepare the base of a house?

   Before building a house you first bring a scheme with you, in your mind. (This time the scheme is drawn on paper. He prepared a rope, two long sticks for the length and two short sticks for the width.)

5. When do you use sticks and when do you use rope.

   One uses sticks when one wants to build a house with small dimensions given that the length of the sticks is very limited. When we want to build a round house, or a house with big dimensions, then we use rope.

6. Could you explain to us the procedure when you are using sticks?

   First one needs to cut 6 sticks using a bush-knife or machete. You put together two sticks on the ground and align the end of one with the end of the other. Then you cut on the opposite ends so that the two sticks have the same length. You do the same with the other two sticks which will be used for the width. After that you lay the two first sticks on the ground side by side, so that the distance between them corresponds to the length of the remaining, already prepared, two sticks for the width. Then you lay down *these two sticks joining their ends with the first two. After that you take position at a certain distance in order to see if the sticks are "kulapi" (ranged). If you notice that the sticks are "ya gongonyoka" (tilted) you take the fifth stick and lay down on the diagonal that is more tilted* (He wanted to say on the diagonal that is longer). *We will start from there making the adjustments. We will try until the stick fits equally in the two diagonals. From this stage on you can mark the place where the two diagonals meet, which will be the place for the "muti uakulimissa nsoy"* (place where the *nzati* will be placed).

7. How do you call the point of *"muti uakulimissa nsoy"*?

   We call "pakati".

8. But *pakati* means "in the middle". Has this name any relation to the base that you were constructing?

   Look! When you are counting steps going straight from a point of the house to the other passing through this point, the number of steps from one point to this point and from this point to the other point will be the same.

9. How do you know that?

   You can count! If you want we can go inside my house and you can count your steps.

10. What I want to know is how do you ensure that it is always correct.

    If it is not correct then the base is tilted, "ya gongonyoka".

11. In the case of using rope, how is the procedure?

    When you are using rope and stick, the builder pins a stick on a reference point of the ground. He makes a knot on the rope so that it can slide on the stick and we are before a compass. He takes another small stick to tie on the free end of the rope und will serve as a marker. So, one can mark the circular base.

12. How do you mark a base like the first one by using rope?

First one pins a small stick into the ground and the construction will begin from there. One ties the end of the rope onto the stick and stretches the rope in a direction which will define the length; coming to the goal with the stretched rope one pins a second stick into the ground and ties the rope onto it. From this point starts the part of the rope that will determine the width. The house builder stretches the rope in that new direction and stops in order to analyze by one's eye if the two parts of the rope are not "very close" or "very open". If the two parts of the rope are laying like the house builder wants, follows the next step. The rope is stretched from the third stick to the fourth and from this to the first forming the desired base for the house.

13. How do you know that this method brings in "perfect" shape for the base?

    Generally it is advisable that by demarcation of the base two or three persons work together for better critical analysis of the base. But, an experienced builder can do well alone. If one thinks that the base is not perfect, one can use rope to verify if the diagonals are equal or not. The stick to be moved is chosen by the first observation from a distance. After the first adjustment the house builder checks again. If he discovers that something is still wrong he tries to change the position of the third or of the fourth stick. The first and the second sticks didn't need to be moved.

14. How can you ensure that a post is well placed?

    One puts the post in the hole and tries to get the post upright (muti vakulimissa nguza). That is done by observation. Keeping someone standing by the post two or three persons observe the post from a certain distance giving instructions to the person near the post in order to put the post well upright.

15. What inclination do you use for the roof?

    The house builder uses a stick and the plane of the ground to show. (We had no tool to measure the angles but, we think that they vary between 60° and

75°.)

16. To what extent does the roof inclination influence the fact that a house drops or not?

    If the roof is less inclined (he reduces the angle between the stick and the plane of the ground) *the roof will drop in a short space of time.*

Some geometrical terms in Cisena:

vertical = muti vaculimissa nguiji

horizontal = nsati

ranged = kulapi

center = pakati pa nsoy

straight = uakuzongoka

curved = gongonyoka

translation = fendeza

7. Interview Sofala-3

Interview with Quizito Pedro Simaportar

(Munhava Central - Beira, 17/11/2000)

Interviewer: Júlio Waéte Chicote

Observer or Assistent: Álvaro Zacarias

The house builder was born in Chemba and speaks Cisena.

Interviewer (**E**) What is your name, and how old are you?

House Builder (**QPS**) My name is Quizito Pedro Simaportar, I'm 17 years old and I was born in Chemba.

E — Who built the house where you live?

QPS — The house where I am living is not my house. I am hiring but, in my native region I built many houses.

E — How did you learn to build houses?

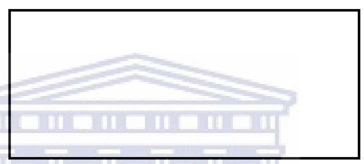
QPS — I learnt to build houses helping and observing my father by constructing our houses when I was still a child. When I needed to construct my own house for a young person — *guero* — I built myself and my father taught me the most difficult parts, such as roof *(nsoi).*

E — How do you arrange or prepare the base of a house?

QPS — • First I prepare the ground or the place where I intend to build the house.

• I find four reeds and cut them with the desired measurements for the house.

• I lay them down on the ground forming the base.

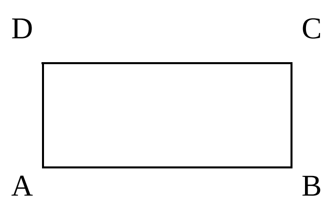


• Adjust well the sides, so that the opposite sides become parallel. I pay more attention to the corners in order to guarantee the solidity of the house.

E — How do you ensure that the base is exactly like you intended to do?

QPS — To ensure that the base is perfect, I use a long reed and I "connect" two opposite corners. With the same measure I connect the other two opposite corners. If the two measurements are equal then I am sure that my house base is perfect.

E — How are you going to straighten the base if you notice that a distance measured by the reed, for example AC, is longer than the another, BD?



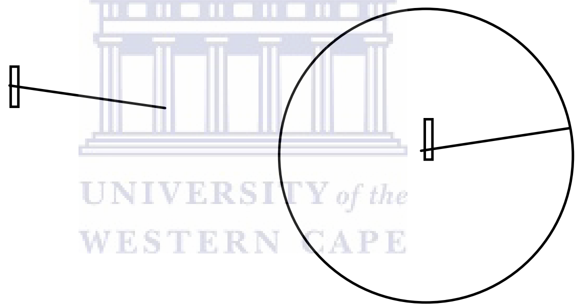
QPS — I will straighten pushing one of the corners, maybe the corner A into inside until the two measurements between opposite corners, using the reed, become equal.

E — How do you know that this method brings in "perfect" shape for the base?

QPS — It's due to the experiences. Whenever my father used this procedure the houses become very perfect without any inclination.

E — Do you know any other method to prepare the base of a house?

QPS — I know. There exists another method to prepare the base for a round house. One pins a small stick on the ground, preferably at the center of the base of the future house. I tie a rope with a desired length to the stick on the ground, stretch the rope and draw a circumference/circle.



E — Did you go to school? Have you learnt these methods at school?

QPS — I attended school but, I didn't learn how to build houses.

E — Where did your father learn these methods and building houses, in general?

QPS — Probably from his father.

E — After doing the base, it's sure that the following step is to place pillars/posts. How do you ensure that a post is well placed?

QPS — One ensures that a post is well upright when the process of verifying the base coincides with the checking of the top.

Comment from author: This answer is not clear. The interviewer should repeat or ask further questions.

E — How do you differentiate, in your mother tongue, a base with all sides equal from a base with two opposite sides equal but not all four equal?

QPS — The bases identify the future house. When the house has a rectangular base in which the difference between length and width is big, the house will be of type *ramada*. If the difference is small or the base is squared, then the house will be of type *nsukuli*. The houses with circular base are also called *nsukuli*.

There exist the so called *góngwè*, the ones in which the difference between length and width is very big.

Comment from author: Both the interviewer and the house builder did not understand the question. The purpose of this question was to "capture" in the builders mother tongue the words for ***rectangle*** *and* ***square****.*

E — What inclination do you use for the roof?

QPS — The inclination has no standard but, the roof must be high so that it doesn't drop when it rains.

E — To what extent does the roof inclination influence the fact that a house drops or not?

QPS — The bigger is the inclination of the roof the smaller is the possibility that the roof drops and the smaller the inclination, the bigger is the possibility that the roof drops.

E — What position or orientation follow the houses you build? What orientation follow the houses that you know, in general?

QPS — Generally the houses face the sunset. Is there where the doors are placed, in general.

(Observation by the author: The sun, in Sofala Province, sets opposite to the sea.)

E — How do you learn to build a house?

QPS — It is easy. It is enough that one is not lazy, that one participates where houses are built.

E — How did you know that you could build a house, yourself (personally)?

QPS — I knew that I was able to build a house myself when I built my first house - guero.

E — What kind of tools do you use? Are there any other tools that you miss for your job?

QPS — In Chemba I used bush-knife, brace *(guara)*, knife and axe.

E — How could you teach anybody to build a house and how long could he/she take to learn?

QPS — Taking him to participate by building a house. He can take a day to learn.

E — By building walls, some builders use lines or rope to tie up the sticks and others use nails. What material do you use, between nails and lines, and why?

QPS — The usual material is rope. Because it costs no money, one can pick it in the bush.

E — In what stages do you divide the building of a house?

QPS — The house building can be divided in four phases: to mark the base; the construction of the walls, the roof construction and the thatching.

E — What is the most difficult stage?

QPS — The most difficult phase is the thatching of the roof.

Some geometrical terms in Cisena:

ranged = ndendende

middle = pakati na pakati

center = pakati

apex or corner = ngomo

curved = gongonyeka

rotation = zungunuka

translation = sussa

8. Interview Sofala-4

Interview with Sebastião António, Macuti Miqueijo - Beira, 16/11/2001

Interviewer: Fonseca Almeida da Fonseca

This house builder speaks *Echuwabu*, from Zambezia Province.

1. What is your name, and how old are you?

   Sebastião António.

2. Who built the house where you live?

   It was me with a couple of friends.

3. How did you learn to build houses?

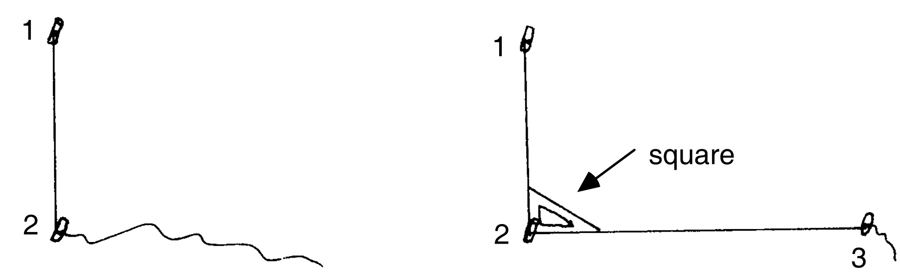
   I learnt observing and assisting my older relatives, my brother and my uncle.

4. How do you arrange or prepare the base of a house?

   First I prepare the ground (leveling);

   Then I pin a stick into the ground;

   Next I pin provisionally another stick in another point of the ground;



   I stretch a rope between the two sticks. I put a square on the second stick and pin a rope from the second stick to a third stick - like you can see in the drawing.

   One takes a rope and measures from the first to the second stick and ties it to another small stick. Measures also from the second to the third stick and *ties also onto the same small stick.*

5. And then?

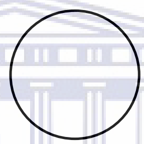
After that, the stick which was tied to the first stick is now tied to the third stick and the stick which was tied to the third stick is tied to the first.

One stretches both ropes and pins the fourth stick. Thus, the rectangle is complete.

6. How do you ensure that the base is exactly like you intended to do?

If one wants to check, one stretches a rope from first stick to the third stick and then from second to the fourth — if the measurement is the same, then the base is correct.

7. If the base was like this? (The interviewer draws a circle.)



Like that is easy. If the house is round, one does like that:

One ties a rope to two sticks and pins one of them into ground. Then one stretches the rope and marks on the ground with the other stick walking around the first stick, and you will see that one comes back to the starting point.

8. How are you going to straighten the base if you notice that it is not correct?

First you put provisional sticks. If it is not correct you can change the places until it becomes correct.

9. How do you know that now the base is correct?

Because of the fact that after measuring it becomes correct.

10. Do you know any other method to prepare the base of a house?

No. I know only these.

11. If you don't have a set square, what could you do?

Without square I can work with a line.

12. How?

You pin sticks in the four corners — it seems to be correct. Then, you stretch the lines like we did before.

13. You did go to school, have you learnt these method(s) at school?

No.

14. Where are the persons, from whom you learnt, did learn these methods and building houses, in general?

They learnt in the same manner.

15. After doing the base, it is sure that the following step is to place pillars or posts. How do you ensure that a pillar is well placed (is well upright?

After placing the post in the hole you take place at certain distance and look to the post. When you are standing in the distance you can see better and easier if the post is inclined or not. Then you go to another position and look again to the post and you vary the positions until you are sure that the post is well upright.

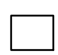
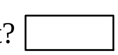
Or you can stand under the post and look to the top. If the post is inclined you will see.

16. How could you say in your mother tongue that this post is upright?

Qui tedamile.

17. How do you differentiate, in your mother tongue, a base with all sides equal from a base with two opposite sides equal but not all sides equal?

.....(Silence)....

18. How could you say that the base has to be this  or that? 

(pointing to drawings on the floor)

<u>*Vipade dho nay dhikale sawa-sawa*</u> *or* <u>*dhikale sawa-sawa billi-billi*</u>.

19. Is there any difference between placing posts for a house of (rectangular) base and for a house with (circular) base? (I used drawings for rectangle and circle, not words.)

It is necessary to follow the line. Both for a square and for a circular base. The post has to be well upright.

20. What inclination do you use for the roof?

    Very inclined. So that it does not drop in short space of time.

21. What position or orientation follow the houses you build? What orientation follow the houses you know, in general?

    The houses can take any position. Depends on the plot of land and where there is a road or a path for people.

22. How does one learn to build a house?

    One learns by looking how the others construct.

23. How did you know that you could build a house yourself (personally)?

    I constructed together with a friend of mine and the house was perfect. From there I knew that I could build a house alone.

24. How could you teach anybody to build a house and how long could he/she take to learn?

    Depends on the person. If he follows me for ca. three months it can be enough. But depends on the competence of the learner.

25. What kind of tools do you use?

    Bush-knife and rope.

26. What other tools do you miss?

    Hammer, nails, pincers and panel saw.

27. What material do you use more, between nails and lines, and why?

    I use more lines but nails are better.

28. Why?

    Because the house structure becomes secure.

29. In what stages do you divide the building of a house?

    — *The base;*

    — *placing posts and beams;*

— *construct the roof and*

— *thatching.*

30. What is the most difficult stage?

The roof.

31. Some geometrical terms in Echuwabu:

1. vertical = qui tedamile
2. horizontal = sawe-sawe
3. oblique = evedhama
4. ranged = eligana
5. middle = vari-vari
6. center = vari
7. apex or corner = komo
8. straight = onyala
9. curved = okoromana
10. diagonal = muguaguanho
11. rotation = ozugunua
12. translation = ofhedhia
13. cone = nguilli
14. cylinder = pinguillizi
15. square = komo dha oligana
16. circunference = yozugunua

9. Interview Sofala-5

Interview with Paulo Justino (**P**), Dondo, 29/09/2001

Interviewer: Elias Alberto (**E**)

Observer or Assistent: Lucas Tomás Mango

E — What is your name?

P — My name is Paulo Justino

E — Who built the house where you live?

P — Myself.

E — How did you learn to build houses?

P — I learnt by observing and assisting other people.

E — How do you arrange or prepare the base of a house?

P — I pin a stick at a place in the ground and from there I take the necessary measures stretching a rope.

E — You have here sticks and rope. Could you show us how do you do?

P — Oh all right! I put a stick here, tie the rope and stretch it until here. Pin another stick of the same size. Now I go to this side *(The house builder stretches the rope to the other side — perpendicularly.)* and pin another stick. If I want that all sides have the same length I take the measure from the side which has the rope already stretched and put the same here. From here I will form the third side following the first side with the same measure. *(The house builder uses the term* following *to refer to parallelism.)*

At the end I join this stick with the first. Now I have the base. From now I can dig the holes for the posts.

E — How do you ensure that the base has the same "folds" in corners? How do you call these "folds"?

P — Nghomu.

E — Well, how do you know that these *nghomu*s are equal?

P — First I take the side measurements. This has to be equal to that, and this one has to be equal to that. *(He speaks pointing to opposite sides.)* Then, looking I can notice that these corners are equal. If it becomes difficult to notice, I go a little bit far and observe. It is easy to see. But, if I want to be very sure I can use a rope. I form the "box" with laying sticks and using a rope I take out this measure and try to have the same here. *(He points to* *the diagonals.).* I will adjust several times until they become equal.

E — And how do you call a "box" of this shape?

P — It is góngwè. *(He is referring to rectangle.)*

E — How do you call it if all these sides are equal?

P — It is góngwè too. I will only say that it is góngwè with all sides equal.

(Observation by the author: Maybe this house builder has influences from school geometry, then square in Cisena is called yapontaponta *and not* góngwè with all sides equal.*)*

E — How do you know that this procedure brings in a góngwè?

P — Because it is like this. If these sides are equal and these too *(referring to opposite sides)* and from here to there is also equal to from here to there *(indicating the diagonals)* then it is a góngwè.

E — Do you know any other method to prepare the base of a house?

P — Another method could be to use *nhamagóngwè* to adjust the corners *(Nhamagóngwè is a can of olive oil with the shape of a block)*. I put it in each corner and adjust the rope with these parts. *(He makes a gesture that indicates that he will use the can's edges as square.)*

E — Why do you trust the *nhamagóngwè*?

P — Because the cannery made it perfect.

E — And how do you form a circular base?

P — I pin a stick at the place that I think that there can be the center of the house and tie a rope to it. I stretch the rope until the desired length and mark a line on the ground. *(He uses the term* redondo *for circular or round.)*

E — Did you learn any of these methods at school?

P — No. I was at school for short time. I attended school until the 2nd grade only, in my time.

E — From where the person, from whom you learnt, did learn these methods and building houses in general?

P — He learnt at the same manner, by observing and assisting other people. In my native village it is obligatory that a young boy helps the men in their jobs even if they are not one's relatives.

While they (the men) are receiving help from the young boys, they explain each step of the house building.

E — By placing the posts, how do you ensure that a post is well placed?

P — After placing the post in the hole I cover the hole with sand without pressing. Then I go far away and observe so that the assistant can correct the position to the indicated direction. I do that in different positions until I am sure that the post is not inclined for any side. To do that I need too to be standing upright. *(He uses the word* swi-swi *to say well upright)*

E — Is it any difference when one places posts for a house with rectangular base and for a house with circular base?

P — In the house of circular base all posts have the same height and the roof has only one apex.

For the house with rectangular base, if the roof has also one apex the posts will have the same height but, for two-sided roof the posts of the "lateral " walls have to follow the inclination of the roof.

E — What inclination have you used for the roof?

P — It is arbitrary. But preferably the biggest possible inclination for the roof so that it doesn't drop.

E — To what extent does the roof inclination influence the fact that a house drops or not?

P — When the inclination is big the rain water wins a big speed over the roof. The rain water speeds over the grass and doesn't go under the grass.

E — What position or orientation follow the houses you build? What orientation follow the houses, in general?

P — Sometimes it depends on the owner's liking. Sometimes one prefers a position, so that the sun rays did not face the door both by sunrise and by sunset. Or, when there is a road near the house, the main door faces the road.

E — How did you know that you could build a house yourself (personally)?

P — After I have assisted and helped experienced builders for several times. The most important is to have the necessary power for that. For the rest it is enough to start. Interested people will come to join you and will help with ideas, correcting what is wrong. Thus, one is getting experience.

E — What kind of tools do you use? Are there any other tools that you miss for your job?

P — I use machete, knife, rope and, when I can, I use nails and hammer too.

E — How could you teach anybody to build a house and how long could he/she take to learn?

P — To teach somebody, first that person has to accept to become my assistant and to be willing to curry out everything that I will order him to do. From that time on I will not carry or take hold of many things. I will only speak. I will direct him to do: to dig post holes, to mark, to take measurements of sticks, to cut stick, etc. He has to accept that I criticize him when he fails or is wrong.

The time that is necessary to learn will depend on the competence of each person. It is better to count in terms of constructions. He has to participate in at least three constructions: in the first, I will build the house and he will assist and help; in the second, he will build the house following my orders and directions, and in the third I will leave him to build freely and I will look only sometimes in order to see some mistakes and to correct these mistakes.

E — What material do you use more, between nails and lines? Why?

P — In the past one used to use rope because it lasts for long time. The nails go rusty and get lost. But, now it is very difficult to find trees which get good rope. Some current ropes can be worse than nails. Because of that one uses now more nails even if they are expensive.

E — In what stages do you divide the building of a house?

P — First is the demarcation of the base; second is the placing of the posts and beams; third is the placement of the roof, and the fourth is the thatching. The fifth phase, that the most of the times is executed by the women, is covering the walls with mud.

E — What is the most difficult stage?

P — The most difficult is the construction of the roof principally when it has only one apex and without central pillar *(nzati)*, given that for this kind of roof the frame may be done on the ground and then placed over the walls — and it is difficult to find the correct position.

Some geometrical terms in Cisena:

1. vertical = swi-swi
2. horizontal = tambalala
3. oblique = peamica/ pendamica/ pendama
4. ranged = dzongoca
5. middle = pacati
6. center = guta
7. apex or corner = n'ghomu
8. straight = lungama/ndendemera
9. curved = funhika
10. diagonal = uguanguanha
11. rotation = phinduza
12. translation = fulussa
13. square = guongwe

14. circunference = redondo
15. pyramid = n'tsoi ya maphufu *(= roof with edges)*

10. Interview Sofala-6

Collective Interview on houses of circular base with the house builders Chico Samo, António and João Manuel , Nhangau, o1/09/2002

Interviewer: Daniel Saores

Observer: Fernanda Mandara

I had already some informal conversations with these three house builders about traditional house building. That day I wanted to have something better registered. So I needed no special presentation of the work that I intended to do. (This interview was not recorded on audio-cassette.)

Daniel — How do you mark the base of a round house?

— *To mark the base is called* kutanda. *To mark a circular base one needs two small sticks and a rope. One chooses the place where will be the center of the house and pins the first stick on the ground. One ties together the two ends of the rope and lays down on the ground so that the stick on the ground is in the ring formed with the rope. One takes the second stick, puts in the ring, stretches the rope and marks on the ground with this stick around the first stick until one comes to the starting point. So we have the base.*

Daniel — How do you mark the positions for the posts?

— *It is by eye, by mental calculation. The place for the door must have more space between the two posts.*

Daniel — How do you ensure that the posts are well upright?

— *First one places one pillar in the hole and determines the desired height. Then one takes it out from the hole and cuts the other posts or pillars using this one as gauge. After that one places all posts and* *passes a rope on the top of all posts in order to verify with a relative facility which post is higher or shorter than the others. To verify if the first post is well upright one has to look to it from inside and from outside of the circle. The remaining posts one can verify walking and observing around the house frame.*

Daniel — How can you determine the size of the roof when it is made outside the house (how do you know that it will fit well in the house?)?

— *The roof is not constructed totally outside the house frame. One selects four thick and equal long sticks and makes a kind of furrow at the thick ends.. These sticks have the name* phalupalu, *in Cisena. One ties the four sticks together passing the rope through the furrows. Then one puts the structure of these four sticks standing. The four ends that work as feet may stay at the same distance from each other and at the same distance from the center. Next one makes two small rings with green poles (called* makassa, *sing.:* kassa*) and ties them one on the outside and the other one on the inside of the four-stick-structure. Then four men take this structure and places it over the round wall with the apex over the* nzati. *One verifies if the apex is well centered and then one adds more* phalupalu *and more* makassa *in order to conclude the construction of the roof.*

Daniel — How do you determine the second circle if the round house has two walls?

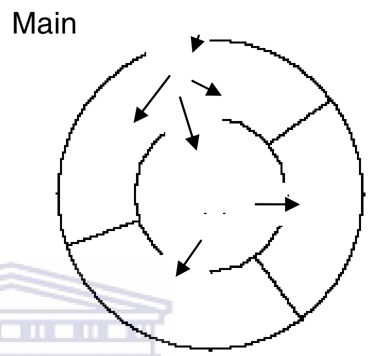
— *It is also with a rope. One begins with the internal wall.*

Daniel — How do you divide the rooms in a house of circular base?

(The house builders make some sketches on the floor)

— *With one wall can have 2 or 3 rooms.*

House with two walls



Daniel — How do you know that the house size is the same both on the bottom and on the top, after placing the beam?

— *One makes two* makassa*, one external and the other internal. Both are made on the base of the posts, on the floor and then they are taken up and tied near the top of the posts. Only then one can place beams in the "mpanda". (Mpanda are the places for beams in forked posts.)*

Daniel — Thank you for your time. I was missing some of this information in my data on round houses.

Appendix B

Example of a field note

In this appendix an example of a page of field notes, done in Portuguese, is shown and the translation in English.

(Translation into English))

Maquival, Friday on the 4th July, 1997

Before the first interview with the house builder Sualé I visited him several times for informal conversations.

Today was one of these days. (I was staying for two days without visiting him because it was raining a lot.)

I decided for visiting him for some times, without paper, pencil and audio-recorder, in order to create a certain confidence among his group before any interviews and other more serious observations.

By the morning I went to meet him and found him smoothing coconut tree pieces that would serve for posts/pillars. He was with his nephew that is ca. 3 years-old.

Given that it was very cold, the nephew was seating down near a bonfire made with coconut palm splinters observing his uncle, and making marks on the ground with a small stick. The rest of the downcast coconut tree trunk was serving as a seat for the small boy.

Some time later came more people, including Sualé's brother, Yassin, who came to help by the construction of a house. They where constructing and at the same time spoke about different issues. By 10:00 o'clock Sualé's wife brought for the house builders something to eat, and asked about when they (the wives) could begin with *omatika* (cover the walls with mud) the future house.

Maquival, Sexta-feira, 4 de julho de 1997

Antes da primeira entrevista com o construtor de casas Sualé, eu visitei-o algumas vezes para conversas informais.

Hoje foi um desses dias. (Eu fiquei dois dias sem poder visitá-lo porque estava a chover bastante.)

Decidi visitá-lo por algumas vezes sem papel, caneta e gravador de som, de modo a criar uma certa confiança no meio do seu grupo antes de alguma entrevista e outras observações mais sérias.

Pela manhã fui ter com ele e encontrei-o alisando uns pedaços de coqueiro que serviriam de postes ou pilares. Ele estava com o seu sobrinho, o qual tem cerca de 3 anos de idade.

Dado que estava muito frio, o sobrinho estava sentado perto duma lareira/fogueira feita com lascas de coqueiro (tronco de coqueiro) observando o seu tio, e fazendo uns riscos no chão com um pequeno pau. O resto da base do tronco do coqueiro servia de assento para o pequeno rapaz.

Algum tempo depois chegou mais gente, incluindo o irmão de Sualé, Yassin, que vinha ajudá-lo na construção duma casa. Eles começaram a construir ao mesmo tempo que falavam de diferentes assuntos. Por volta das 10:00 horas a mulher de Sualé trouxe aos construtores algo para comer, e perguntou sobre quando é que elas (as mulheres) poderiam começar com "ematika (cobrir as paredes com terra ou barro) a futura casa.

Fig A1: Example of a field note sheet

Appendix C

Inquiry guides from ARPAC-SOFALA (Cultural Heritage Archive) on traditional dwellings and villages

Looking for earlier literature on traditional house building in Sofala Province the researcher found interview transcriptions done in the early 1980s on behalf of the former Ministry of Education and Culture, National Service for Museums and Antiques, with the designation *Cultural Preservation and Valuation Campaign*, kindly loaned by ARPAC-SOFALA (Cultural Heritage Archive)

Translation of the first part of the inquiry guide from National Service for Museums and Antiques:

CULTURAL PRESERVATION AND VALUATION CAMPAIGN

NATIONAL SERVICE FOR MUSEUMS AND ANTIQUE

INQUIRY ON TRADITIONAL VILLAGE

NAME OF THE INFORMANT ___________________________ ethnic group ___________

Sex _____ age _________ profession _____________________________________

Collection place: Province ________________ District ______________________

Locality ________________ circle ________________________ Name of the collector ___________________________ function ____________________________________

Working place ____________________________ Collection's date _______________________

QUESTIONS:

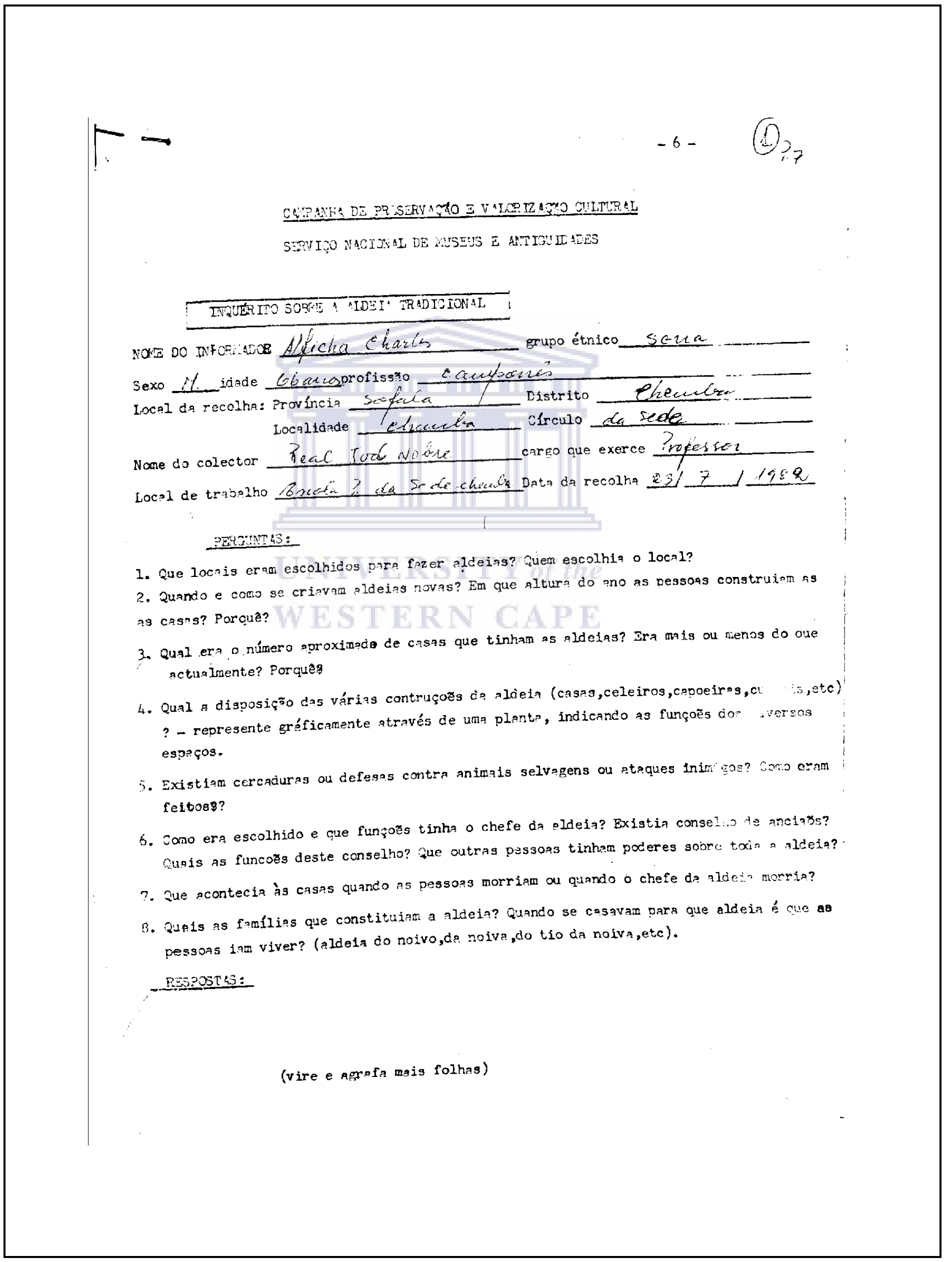
1. Which places were chosen to establish villages? Who chose the place?
2. When and how were new villages established? In which season will people build houses? Why?
3. How many houses had each village, approximate number? Were they more than or lesser than in our days? Why?
4. How are the different constructions arranged in the village (houses, granaries, hen-houses, enclosures, etc.). -- make a graphic representation, through a plan, indicating the function of each space.
5. Do there exist fences or defenses against wild animals or enemy attacks? How were they constructed?
6. How were the village's head chosen and which role had the village's head? Do there exist an elders' council? Which were the functions of that council? Which other persons had power

over the whole village?

7. What happened to the houses in cases of owner's death or when the village's head died?
8. Which families constituted a village? When anyone was married, to which village must one move? (bridegroom's village, bride's village, bride's uncle village, etc).

<u>ANSWERS</u>

(turn over and staple more paper sheets)



- 6 -

CAMPANHA DE PRESERVAÇÃO E VALORIZAÇÃO CULTURAL

SERVIÇO NACIONAL DE MUSEUS E ANTIGUIDADES

INQUÉRITO SOBRE A ALDEIA TRADICIONAL

NOME DO INFORMADOR Alficha Charles grupo étnico Sena

Sexo M. idade 66 anos profissão camponês

Local da recolha: Província Sofala Distrito Chemba

Localidade Chemba Círculo da sede

Nome do colector Real João Nobre cargo que exerce Professor

Local de trabalho Escola 1ª da Sede Chemba Data da recolha 23/ 7 / 1982

PERGUNTAS:

1. Que locais eram escolhidos para fazer aldeias? Quem escolhia o local?
2. Quando e como se criavam aldeias novas? Em que altura do ano as pessoas construiam as as casas? Porquê?
3. Qual era o número aproximado de casas que tinham as aldeias? Era mais ou menos do que actualmente? Porquê?
4. Qual a disposição das várias contruçoẽs da aldeia (casas,celeiros,capoeiras,cu...is,etc) ? – represente gráficamente através de uma planta, indicando as funçoẽs dos diversos espaços.
5. Existiam cercaduras ou defesas contra animais selvagens ou ataques inimigos? Como eram feitos?
6. Como era escolhido e que funçoẽs tinha o chefe da aldeia? Existia conselho de anciaõs? Quais as funcoẽs deste conselho? Que outras pessoas tinham poderes sobre toda a aldeia?
7. Que acontecia às casas quando as pessoas morriam ou quando o chefe da aldeia morria?
8. Quais as famílias que constituiam a aldeia? Quando se casavam para que aldeia é que as pessoas iam viver? (aldeia do noivo,da noiva,do tio da noiva,etc).

RESPOSTAS:

(vire e agrafa mais folhas)

Fig. A.2: Inquiry guide from National Service for Museums and Antiques (first part)

Now one will present the translation of the second part of the inquiry guide from National Service for Museums and Antiques, *on traditional dwelling*, that was more useful for this research.

Unfortunately, the print quality was not so good to be scanned. So, one will present the translation only.

CULTURAL PRESERVATION AND VALUATION CAMPAIGN

NATIONAL SERVICE FOR MUSEUMS AND ANTIQUE

TRADITIONAL DWELLING

NAME OF THE INFORMANT ___________________________ ethnic group ___________

COLLECTION PLACE: Province ________________ District ______________________

Locality ________________ circle ________________________ HOUSE

LOCATION: isolated ☐ group of houses ☐ How many houses? _____ Valley ☐

range ☐ tableland ☐ coast ☐ others _____________

____

How many house types exist in the region ________ Write the local names ___________________

____________________________________ How is this one called _______________________

Other type of constructions and utility areas near to the house ______________________________

____

____

materials and construction techniques:

roof ____

____

____

Walls (Interior and exterior) ____

____

____

doors and windows ____

____

floor ____

house type: ☐ ☐

round rectangular other _________________

house builders (men, women and the function from each) _________________________________

____

Has the house decorative paintings? ______ Which kind? ______________________________

How many divisions has the house? _____ For what? _____________________________________

____

Number of people living in the house: men _______ women ________ boys _______________

girls ________________ children __________________

Collector's name _______________________________ collection's date _________________

Function _________________________________ Working place _______________________

On the back side of the sheet one finds a pointed paper with following tasks:

DRAWINGS:

<u>Inventory of the dwelling</u> (houses and other auxiliary constructions, like granary, hen-house, housing for cattle, cemetery, holy tree, etc.)

Each space between two points (0,5 cm) corresponds 1 metre (one big step)

(space of 32 per 24 points)

scale 1/200

<u>Facade of the principal house</u>

Each space between two points (0,5 cm) corresponds half metre 0,5)

. . . .

. . . .

(space of 32 per 17 points)

scale 1/100

Appendix D

Using the results of the pilot study the researcher tried to demonstrate that the sense of verticality must not be learned first at school but that one is born with it, ie, one has an inert intuition for it.

In order to test and to validate or not this idea that *the sense of verticality is something natural, which one is born with*, the researcher interviewed four school children, who never had contact with house builders, in order to check how primary school children determine the verticality of a stick and if they understand the concept *verticality* (***to be upright*** **= wimela dereto**).

Before presenting the four interviews one will present a short version of the method of placing posts used by house builders of the southern region of the Mozambican province of Zambézia (Echuwabu speaking people).

First the house builder marks the spots where holes should be made for the posts. After this, the builder begins to open the holes to the necessary depth. In order to place the first post well upright, the builder needs the help of an assistant, who has to carry out the builder's orders.

The first post having been put in its hole, the master takes a position at a certain distance and, turning to the post, he examines that the post is not inclined neither to his left nor to his right side. In order to do this, he looks a number of consecutive times to the base and the top of the post, always glancing over the whole post with his eyes (Fig. A.3a). If necessary, he orders the assistant to incline the post more to the left or to the right. When he thinks that the post is well upright, he fixes it in the hole from the left and from the right side. Next, he takes a new position, in a direction to the post that is approximately perpendicular to the former direction (Fig. A.3b).

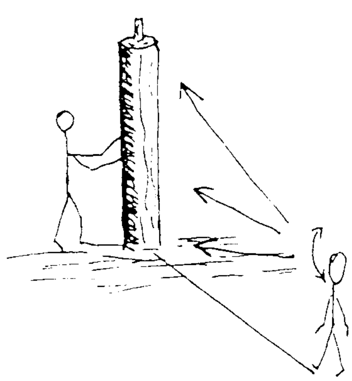


Fig. A.3a

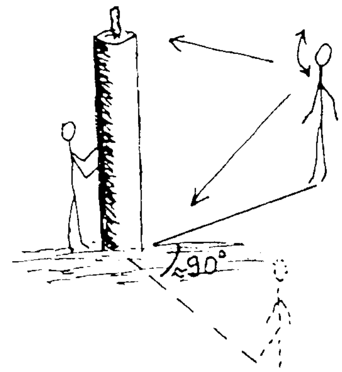


Fig. A.3b

As before, he makes sure the post is not inclined neither to his left nor to his right side. After having ordered to straighten the post's position in this direction, he returns to his former position because he wants to check whether the post has not been exposed to a deviation in the other direction. Finally, he orders the post to be *fixed* in its hole.

The demonstration of this idea cannot be only geometrical. It is both psychological/physiological and geometrical. First, the researcher thinks that it is acceptable that the sense of verticality is something natural, which one is born with. It (the sense of verticality) is going to develop with one's growth. When someone, even a child, is trying to standing up with the feet in different levels of the ground, he does not need a long while to think that he must not stretch both legs. Because he can fall down. It is this sense of verticality who helps someone to decide if a stick or a tree trunk is upright or not, at least related to the plane in which his body and the base of the stick or of the tree trunk are. One is referring to a standing up body. Because, when the person is not standing up the question of discussing if a certain object is properly upright or not becomes more complex, and will not be discussed in this work.

Now one will present the four interviews (Beira, Mozambique, March 2001). The interviews took place on the beach in order to avoid the influence of artificially vertical created objects. Therefore, it could happen that house walls, flagpoles, pole beams, window and door frames influence the children to decide if a stick fixed in the beach's sand was in the vertical position or not. So, on the beach the stick was practically placed with *no vertical reference point or line.*

Child A: Eufrásia (F), 7 years old, standard/grade 3

Interviewer: **DS** (Daniel Soares, the researcher)

DS: What's your name?

A: Eufrásia.

DS: Are you a student?

A: Yes, I'm.

DS: Which grade?

A: Standard 3.

DS: How old are you?

A: I'm 7.

DS: Now you are going to tell me if that stick is upright. Look to it... What do you think? Is it upright or not?

A: It's bent a little bit.

DS: How do you notice that?

A: Ah ah!...*(laugh)* This way. *(And makes a gesture with the righten hand glancing the stick from the top to the bottom but, from the same place, so without touching the stick.)*

DS: How did you notice that it's bent a little bit? Where to is it bent?

A: It's to this side. *(Pointing at the stick top.)*

DS: Which side? That side? ...

A: Yes.

DS: ... of the road/street?

A: Yes.

DS: How can you see that from this side? How can you see that the other side is tilt?

A: Aha!...*(Laughing)*

DS: Give right answer. If I say that it's not, what are you going to do in order to show me that it is?

A: I don't know.

DS: Don't you now?

A: No.

DS: Ok, thank you!

NOTE: *In fact the stick was tilt at the indicated direction, but from the position where she was standing up, she couldn't be sure enough of the situation.*

Child B: Valdo (M), 9 years old, grade 3

Interviewer: **DS** (Daniel Soares)

DS: What's your name?

B: Valdo.

DS: How old are you?

B: I'm 9.

DS: Are you a student?

B: Yes.

DS: Which grade?

B: Standard 3.

DS: You're studying in standard 3. Ok. Now tell me if this stick is upright or not.

B: Yes, it is.

DS: Check it first.

B: *(Valdo walked 1/4 around the stick and stand)* The stick is almost tilt.

DS: Where to?

B: To, to... What's this side?... *(He points at the his left side with the hand.)*

DS: It's your left side.

B: The stick is tilt to the left side.

DS: Mhum! ... What did you do to notice that it's tilt to the left?

B: Because ...

DS: Uhm ?...

B: ... I observed the stick ...

DS: Mhum...

B: ... and I was able to see.

DS: How did you observe?

B: ..... *(Silence.)*

DS: Explain what you did.

B: ..... *(More silence)*

DS: Ahm ... Now you are looking up, aren't you? *(He was looking at the top of the stick.)*

B: Hum... I don't now how to say.

DS: But how did you do? I saw you looking at the top of the stick.

B: Yes.

DS: What else have you done to notice that it's bent? *(In this case bent means tilt)*

B: It's tilt because I saw it. This side ... it has almost nothing *(He points at the top of the stick.)* and this is looking too much at this side, on the left. *(He points at the top of the stick.)*

DS: Is the top looking at the left side?

B: Yes.

DS: Ok, thank you?.

NOTE: *In fact the stick was tilt to the indicated direction, and he proceeded correctly in order to see if the stick was upright or not.*

Child C: Fife (F) 9 years old, grade 4

Interviewer: **DS** (Daniel Soares)

DS: What's your name?

C: Fife

DS: How old are you?

C: I'm 9.

DS: Nine years. Do you study?

C: Yes.

DS: Which class?

C: Standard 4.

DS: Standard 4. Ok. Now you are going to tell me if this stick is upright or not.

C: It is.

DS: Is it? How do you see it?

C: *(Silence — She starts looking at the stick, without saying anything.)*

DS: What are you doing now to see it?... I'm seeing that your eyes are moving. How are your eyes moving?

C: Well.

DS: How are you observing it?

C: *(Silence — The child is still looking at the stick, without saying anything.)*

DS: How do you observe to notice that it's tilt or ... You look, for example in the middle? ... How you...

C: No.

DS: What do you do?

C: From the top to the bottom.

DS: From the top to the bottom. Once?

C: Yes.

DS: Mhum! Ok! If I do this now? *(I pushed the top a little bit opposite the interviewer.)* Is it still upright? ... Is it? ... Is it?

C: It is?

DS: Ok! Let's go that side. *(We walked round the stick about 90° to the other side.)* Now tell me from here. Is it upright?

C: It is! *(In fact my push did not produce any effect)*

DS: Aham! Just wait a little bit. *(Without seeing, I bent the stick to the front which was our left side before.)* Mhum, what do you say now, is it still upright?

C: No.

DS: Why?

C: It's a little bit tilt.

DS: Where to?

C: To that side.

DS: That side. How do you see from here... how do you see that it's tilt?

C: *(Silence — It was difficult to know what the child was doing at the moment.)*

DS: If I say that it's not tilt, what are you going to do in order to show me that it's tilt (to) that side?

C: I?

DS: Yes.

C: I will catch it this way. *(The child accompanying her words with gesture as* *if she was going through the stick from the bottom to the top, from the back to the front.)*

DS: To show?

C: Yes.

DS: But, without holding it, how can you do it? From here I think it's not tilt, but you say that it is. What are you going to do to show me that the stick is tilt, without touching it?

C: Mhm! ...

DS: What are you going to do?...Think a little bit! Will you continue explaining me from here where to it's tilt? What are you going to do? In order to show me that it's tilt, what should I do or what are you going to tell me (that I should) do, without holding the stick?

C: To observe carefully.

DS: Aham ... From here?

C: Yes.

DS: But from here I see that it's not bent?

C: *(Silence)*

DS: Is it?

C: It is.

DS: Mhum. It's ok, that's right.

NOTE: *In both situations the child was right in the positions of the stick, but the procedures were not enough to affirm with security that she was judging correctly. She trusted on what she observed from only one position.*

Child D: Natacha, 11 years old, standard/grade 6

Interviewer: **DS** (Daniel Soares)

DS: What's your name?

D: Tach... Natacha. *(At home she is known as Tachinha.)*

DS: Natacha, how old are you?

D: Eleven.

DS: Do you study?

D: Yes.

DS: Which class?

D: Standard 6.

DS: Standard 6?

D: Yes.

DS: I have this stick, which I pricked here in the beach's sand. Now you are going to tell me if it's upright or not?

D: This stick is not, it's bent a little bit. *(Here the word* bent *means* tilt.*)*

DS: Where to?

D: To the back.

DS: Where is the back?

D: There, the back of the stick. *(She was referring to the opposite side of the stick, where we could not see.)*

DS: How do you notice that?

D: *(Silence.)*

DS: If I say that it's not tilt, what are you going to do to show me that it is?

D: I am going to point it.

DS: How are you going to point it?

D: I'm going to point the back side.

DS: Aieh!... How are you going to do? Show me!

D: It's here. It's a little bit to here. *(The child was pointing the stick from far, from a position which was on my left side, about 90° from the position where I have been and she was moving her right hand to the left, saying:)* It's a little bit to this side.

DS: So, when you move to that position, is it noticeable that it's bent?

D: Yes.

DS: Ahm! So it's not by pointing. It's by moving the position and then show it. Now where is it tilt to? *(The interviewer joined the child at the new position.)* From there you said that it was tilt to the back, and what about from here, where is it tilt to?

D: Over there. *(The child said that without (accompanying with) gestures.)*

DS: Over there again? Which side?

D: *(Silence.)*

DS: Wait. Let’s go back to the first position... Where is it tilt from here?

D: To the back.

DS: There, isn’t it?

D: Yes.

DS: Now, from there where we have been? Let’s go there again!... Now that we are back, where is it tilt to?

D: To the same place.

DS: But, now isn’t *over there*?

D: Yes. *(This* Yes, *means* No.*)*

DS: Now, it’s not to the back, where to?

D: It’s sideways.

DS: On the right side, isn’t it?.

D: Yes.

DS: Aham! Ok!

At the end the researcher asked all four children if they have learned what they related to him at school or at home. All of them said that it was the first time that they played a similar “game”. They have learned that neither at school nor at home. However, some of them remembered the concepts of vertical and horizontal at school (from blackboard notes and on the exercise books), but not with concrete objects, and not in space.

However, it is evident that they have been confronted with real situations related to verticality, but not consciously. Verticality in the plane, in the real world can appear by observing certain pictures on house walls, looking at window and door frames, etc. In space the verticality can appear when one looks, for example, to a tree trunk. The tree trunk can be vertical or tilted. And, depending on the position from where one looks to the tilted tree trunk, it can seem more or less tilted. Herewith the researcher thinks that his idea that *the sense of verticality is something natural, which one is born with* was confirmed.