USE OF MATHEMATICS IN MAKING STUPA

A

THESIS

BY

RUPESH B.K.

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Letter of Certificate

This is to certify that **Mr. Rupesh B.K.** a student of the academic year 2072/073 with Campus Roll no 262/2072-073, Exam Roll No.7228378 and T.U Registration Number 9-2-257-75-2012 Thesis No. 1522, has completed his thesis under the supervision of Tika Ram Pokhrel during the period prescribed by the rules and regulation of Tribhuvan University, Nepal. The thesis entitled, **"Use of Mathematics in Making Stupa"** has been prepared based on the results of his investigation conducted during the period of 2022. I hereby, recommend and forward that his thesis is submitted for evaluation as a partial requirement to award the Degree of Master of Education.

.....……

Prof. Dr. Bed Raj Acharya

(Head)

Date: 2nd May 2022

Letter of Approval

This thesis entitled **"Use of Mathematics in Making Stupa"** submitted by **Mr. Rupesh B.K.** for the partial fulfillment of the Master's Degree in Education requirements has been approved.

Viva Voce Committee	Signature
Prof. Dr. Bed Raj Acharya (Chairman)	.....
Prof. Dr. Binod Prasad Dhakal (External)	.....
Tika Ram Pokhrel (Supervisor)	.....

Date: 23rd May 2022

Recommendation for Acceptance

This is to certify that **Mr. Rupesh B.K.** has completed his M. Ed. Thesis entitled **"Use of Mathematics in Making Stupa"** under my supervision during the period prescribed by the rules and regulations of Tribhuvan University, Kirtipur, Kathmandu, Nepal. I recommend and forward his thesis to the Department of Mathematics Education to organize a final Viva-Voce.

…….

Tika Ram Pokhrel

(Supervisor)

Date: 2nd May 2022

Defense Date: 23rd May 2022

Dedication

This thesis is dedicated to my mother Chameli Kami, uncle Jagat Sunar and aunt Janaki Sunar**,** who have been supporting me in every step of my life and have been my source of inspiration.

Declaration

This thesis contains no material which has been accepted for the award of other degree in any institution. To the best knowledge and belief, this thesis contains no materials previously published by any authors except due acknowledgement has been made.

…….

Rupesh B.K.

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……..

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Abstract

This study; Use of mathematics in making stupa was conducted to explore the use of mathematics in making stupa and to suggest the pedagogical implications of mathematical practices in making stupa. The study used the ethnographic approach with a qualitative method for data collection. Interview, participant observation and artifacts were the main sources of data. The study was conducted in two stupa making factories viz. Stupa Handicrafts Company, Gwarko, Lalitpur and Copper Carbine Handicraft, Swayambhu, Kathmandu.

Results and interpretation of the data from the study showed that the artisans use fundamental concepts of mathematics blended with the traditional knowledge. Such mathematical knowledge has been passed from generation to generation through trainings and experiences without formal education and curriculum of stupa design and construction. This showed that the artisans make use of graph, vertex, coordinate, lines, parallel lines, triangle, rectangle, square, circle, sphere, unitary method, similarity, congruence, reflection, enlargement, and symmetry.

The study explored a number of pedagogical implications of mathematical practices. Construction of stupa is a concrete example of practical use of mathematics. Making of the stupa involves mathematics from initial planning to the final structure. School education could be connected with it so as to develop teaching methodologies and develop stupa as a teaching material.

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Chapter I

Introduction

Background of the Study

Mathematics is the study of quantity, structure, space, numbers and science and it developed with abstraction and logical reasoning from counting, calculation, measurement and from the study of shapes and motions of physical objects. Mathematics began with human civilization and practice. In the ancient period, mathematics was originated from counting by using pieces of stones and by cutting notches in a piece of sticks or by tying knots in a string with gradual evolution of society (Eves, 1981).

The concept of mathematics began from the very beginning of the human civilization, and developed with the advancement of science and technology. The gradual development of mathematics took place (lamichhane, 2017). The beginning of human history, every culture has developed its own mathematical ideas and different practices. In some cases, these ideals and practices have been transmitted and diffused from one culture to another (Orey and Rosa, 2011). From above both represents mathematics developed even in the development of human race and with the different kinds of works. It showed that different cultures have different mathematical ideas of mathematical concepts and have mathematical knowledge and it had been using from the different works. In the history of mathematics, there were different views of mathematics. Mathematics has a significant role in the development of human civilization throughout the world and seeing it as socio-cultural and historical entities makes it obvious that it's taught and learned (Hersh, 1997).

Development of mathematical concepts is a major achievement of human civilization. Astrology, structural design, oceans, measurement system, economic planning and transaction are some of the areas, which need the use of developed mathematical concepts and reasoning. Developments in this field had started in early periods of history in china, India and the Mediterranean modern endeavors at scientific investigations and technological advancements cannot be done in isolation, i.e. without mathematics. Mathematics may be considered a special kind of language

developed to convey quality, shape, position etc. and their interrelationships. Its use is determined by rules of logic-the logic that emanates from the law of nature (CERRID, 1990).

Ethno-mathematics. The study of the interrelationship between mathematics and culture. There are so many mathematical knowledge in culture so this mathematics knowledge linked with curriculum that is ethno-mathematics. According to D'Ambrosio (1985), ethno-mathematics is "the mathematics which is practiced among identifiable cultural groups such as national-tribe society, labor group, children of certain age brackets, and profession classes". Ethno-mathematics can be summarized as practiced by the members of a cultural group who share similar experience and practices with mathematics that can be in unique form. All these cultural groups have their own language and specific ways of obtaining the practical mathematics, and ethno-mathematicians study and their technique, (Cimen,2014). It shows that, Artisans are one of the skilled occupational groups. They have also their own mathematics, which is used for solving their working problems. Making of stupa is one of the examples which involves the use of mathematics in many forms. They use copper plain sheet to make stupa. They use their traditional mathematical skills for their works, which are not learnt from any school rather from the trainings and experiences of their forefathers. They use different tools such as hammers, tongs, chisels etc. to make the stupa

Stupa. The word stupa (pali 'thup'; Anglo-India 'tope') derived from the root 'stup' (to heap) is a mound or tumulus. According to ancient tradition, its other synonyms are caitya and dhatugarbha in Sanskrit, Chiba in Newari and Mchod rten in Tibetan. Originally they were associated with funerals, being mounds containing the ashes and charred remains of the dead collected from the funeral pyre. The practice of erecting stupas over corporeal relics was pre- Buddhistic. (Chan, 2013). Literally, stupa denotes a made up heap of earth or of any other materials to serve a specific purpose. (Dorjee,1996).

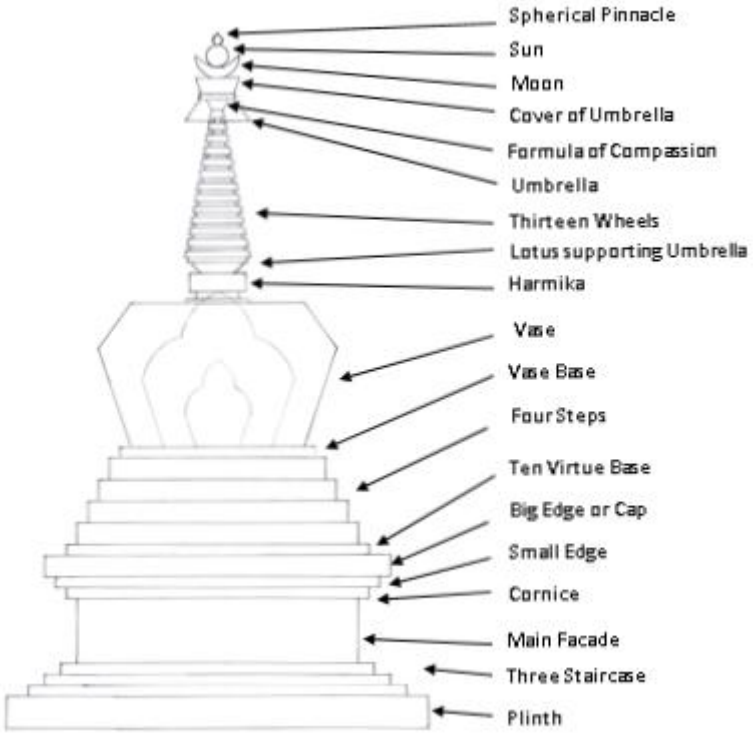


Figure 1. 1 Plane figure of Enlightenment Stupa

Buddhist Stupa, the often massive hemispherical mounds built for the veneration of Buddha and his disciples, were undoubtedly the most magnificent religious monuments that appeared in the India subcontinent during the early historic period. The origins of the stupa are not entirely cleared, but in Buddhist contexts they would seem to have appeared at some point around 400-300 BCE. The practice of building them became prevalent throughout South Asia between C. 200 BCE and 300 CE and soon spread to other parts of Asia (Hawkes & Shimada, 2008).

Stupa consists of three receptacles which represent the body, speech and the mind of the Buddha: a painted image or statue or statue of an enlightened Buddha, or deity, forms the receptacle of body; a religious text forms the receptacle of enlightened speech; and a stupa forms the receptacle of Buddha's enlightened mind. The stupa is essentially the earliest form of the Buddha image, built to commemorate the major events in his life and to mark the sacred places where these events occurred, and to house his relics as well as those of his spiritually advanced disciples (Robert,1999).

Eight forms of Buddhist stupa are in practice from the ancient period. Mahabodhi stupa is one of them which is the one the research has been carried out. Mahabodhi stupa is the 'stupa of conquest of Mara' or 'Enlightenment stupa', commemorating Shakyamuni's defeat of the temptation and attack of the hosts of Mara under the Bodhi tree at Bodh Gaya, when he was thirty-five years old. King Bimbisara is said to have erected a stupa of this design, often with a slight overhang along the top of each step (Robert, 1999)

Statement of the Problem

Generally, the perception of the normal people who are not literate by mathematics education is that the mathematics is one of the subjects taught in formal school. Many don't find the relation between mathematics and the day to day work. But the people have learned similar mathematical knowledge in the society knowingly or unknowingly. They acquire mathematical knowledge from their society, culture, day to day interaction, practical works, observation, experience and so on. There is gap between school mathematics and people's perception towards mathematics. In this situation math educator should fill the gap between school mathematics and practical mathematics which are used in our surroundings and in our everyday lives that helps to normal people to understand the mathematics in their own real life situation.

Nepal is a culturally diverse country. There is numerous caste, religious, occupational groups, languages and cultures. This also indicates that our schools are also multi-cultural, multi-lingual, and multi-occupational. The first school of a child is his/her home, so the children learn more from their own home. They learn what their environment teaches them. As they move to schools and start learning different ways, they find the school teaching methodology completely different and complex. This makes them confused and difficult in understanding. If mathematics educator connects the mathematics with their working practice, it surely helps the child to understand the mathematics more easily and clearly. The children will enjoy mathematics. The fairness/ anxiety of children toward mathematics can decrease. This study focused on how mathematics is used particularly in making stupa.

Objective of the Study

The study attained the followings objectives.

- To explore the mathematics ideas used in making Stupa.
- To suggest the pedagogical implications of mathematical practices in making stupa.

Research Questions

The research attempts to seek the following research questions

- What are the use of mathematics in making stupa?
- What might be the pedagogical implications of mathematical practices in making stupa?

Rationale of the Study

There are numerous ethnic/ caste/religious groups in Nepal and they have own occupation and lifestyle. They have their own mathematical knowledge which they used to solve their occupational problems. Mathematics education research should be linked to those mathematical ideas practiced by different cultures and occupational groups with the school mathematics. If those ideas used by those groups are related to school mathematics and their acquisition of mathematical knowledge is practical and experimental. The teacher can use the mathematical ideas of special mathematical concepts which are existed in his/ her surroundings, which helps students to understand mathematical concepts.

This study would reflect the indigenous mathematical knowledge. This study is helpful for mathematics teachers, teacher trainers, researchers, educators, students, mathematicians and other people who are interested to understand the artifact of culture of Buddhism. This study focused on what are the mathematical knowledge practiced in making stupa and how it connects to formal education system.

The followings points were considered to be the significance of the study,

- Specially, it is helpful for the teachers of Gumba or Bihar education school to link or connect the day to day classroom practices of stupa, which increase students understanding.
- This study provides knowledge about cultural mathematics related to school mathematics with its pedagogical implications used in making stupa.
- This study promotes the ethno-mathematical research,

Delimitation of the study

The study is an ethnographic study about the stupa created by a group of Artisans. In general, Stupa is made of many types of materials, but this study only includes stupa made with copper. There are eight different forms of Tibetan stupas but the study included Mahabodhi Stupa only. It was a study of short duration (4 months) conducted on 2076/08/01-2076/11/30.

Operational Definition of the Related Terms

Meaning of the following words are whatever in the other contexts but in this research these words give the following meaning.

Buddhism. A widespread Asian religion or philosophy, founded by Siddhartha Gautama in Nepal in the 5^{th} century BC.

Artisans (Kaligadh). An Artisan is a skilled craft worker who makes or creates material objects partly or entirely by hand. In this study, an Artisan is a person involved in making stupa.

Tathāgata. It is a Pali word; Gautama Buddha used it when referring to himself or other Buddhas in the Pāli Canon. Tathagata is an honorific title of a Buddha, especially the Buddha Gautama, or a person who has attained perfection by following Buddhist principles.

Chapter Summary

In this chapter, I dealt with the background of the study, statement of the problem, purpose, research questions and concluded it by discussing the delimitations

of my study. I also discussed the concepts of ethno-mathematics and everyday use of it by the people and how they can be related to the formal classrooms of mathematics teaching. Likewise, I also discussed the use of mathematics by artisans knowingly and unknowingly in their everyday work without any formal knowledge of mathematics.

Chapter II

Literature Review

This chapter deals with empirical and theoretical reviews correlated to 'Making of stupa'. It explores what other researchers say about the relationships between ethno-mathematics and the mathematics taught formally in the schools' classrooms. I try to establish a link between my research issue and the sociocultural theory of making of Stupa. Likewise, I reviewed previous studies in this area and summarized their objectives and conclusions which assist me in identifying gaps for my study. I create my conceptual framework for my research. Finally, this chapter ends with the gap that I have noticed in the previous studies that my research aims to fill in.

Empirical Literature Review

The empirical literature is that literature, which is authentic knowledge from research. These literatures provide methodology and procedures in the related topics.

Millroy (1992) conducted an international research on "An ethnographic study of the mathematical ideas of carpenters". A six-month ethnographic study as an apprentice carpenter in Cape Town, South Africa, to document the valid mathematical ideas that are embedded in the everyday woodworking activities of the group of carpenters. Another objective was to examine and to give a first-hand account of the teaching and learning mathematical ideas in the context of researcher's apprentice. The methodology of the study was participant observation. The result shows that the many mathematical concepts are embedded in the practice of the carpenters. They made extensive use of the concepts of congruence, symmetry, proportion, straight and parallel lines in their everyday works. The result also showed that the carpenter's mathematical ideas have several unique characteristics. There was tacit mathematical knowledge in their action and reflection and actions led them to concrete contextualized problematic and their ideas were formed by the concept of the workshop and carpentry tools. Comparison, using the senses of touch and sight was preferred to measuring and usually resulted in optimal solutions. The epistemological, educational and methodological implications of these results and discussed.

Also, Gelsa, (1995) conducted a study on "Culture, mathematics education in the struggle for land". This was the political action with the objectives of occupying the land which according to the Brazilian constitution, are subjected to exploration for land reform. The ethnographic research of Gelsa focused on identifying the ethno-mathematics of these processes and supporting instruments to integrate for their immediate needs and allowing the transition of the official school system after overcoming the legal obstacles. The way of conducting the research training for this parallel education system, relying, of course, on human resource provided by uneducated confined population is a major challenge.

These two research shows that the use of mathematics is everywhere. The carpenter used similarly to the school/ formal mathematics in their own ways. And the lawyer also used mathematics to solve their problem related to the land reform.

Similarly, Wolfgang (2015) conducted a study on "The Traditional Newar Architecture of the Kathemandu Valley, The Stupa and the chaityas". This study was the exclusive study of the Buddhist stupa and chaityas big and small in the kathemandu valley. He describes and demonstrates their various types and sites plans with aid of his own state of the art systematic line drawings. Several stupa and chaityas belonging to the periods of Licchabi, malla and shah including their distinctive features such as décor elements and building materials are described in the plain language. Religious and legendary monuments such as the svayambhu stupa, the Boudha stupa and the Asokan stupa along with historical information and detailed line drawings are presented. "The Traditional Newar Architecture of the Kathemandu Valley, The Stupa and the chaityas" contributes significantly to Buddhist power places and their traditional Newar architecture of the kathemandu valley. It is indeed the authentic reference for next generation students and scholars who are working on traditional architecture in general and conservation architecture in particular. While this research explored the basic mathematics used in making stupa and how such mathematics could be connected to the school education.

Regmi, (2007), conducted the study on "use of mathematics in teaching guitar." The objectives of the research were to identify the mathematics used in Rhythm and Plucking and to identify the mathematics used in Bass and Lead. The design of the study is qualitative observation and review of the documents and

intensive interview with the responds were the major techniques/methods of data collection. The study found that the natures of mathematics used in western musical instrument guitar is mostly basic Arithmetic, Rhythms. Plucking, Rhythms, Bass and lead are the four main streams of music and need mathematics. Natural number, Whole number, fraction numbers, index number, L.C.M., Addition, Addition of fraction number, Ratio, Time, Point, Triangle, Square, Circle, straight line, Angle, Circle with diameters, decreasing geometrical sequences and Factorial are used to playing guitar. The nature of teaching of the integrated contents of mathematics in classical guitar education was demonstration, discussion and directed teaching. Regarding the efficiency of teaching, the teachers who had mathematical background was teaching effectively.

In the context of Nepal there are some study in ethno-mathematics. In this way, Kunwar, (2007) carried out the study entitled "Mathematical Use in Tailoring, A Case Study of Uneducated Pariyar in Tailor Profession". The objective was to find out mathematical uses in tailoring and process of acquiring mathematical concept. The methodology of the research was participant observation and a semi-structured interview. The researcher found that the tailor acquired mathematical concept through experience and practice of tailoring. The method of learning mathematical concepts is learning by doing, observation, imitating. The researcher also found that the society was a source of knowledge in a different manner.

In the same way, Paudel, (2007) conducted the study on "A Study on the Mathematical Skills Use in Tailoring". The objective of the research was to find mathematical concepts needed for tailor master and their acquisition of mathematical knowledge. The methodology was participant observation. The study found that many conventional mathematical concepts are embedded in the practice of the tailoring. Tailors use many mathematical concepts such as the plane, perpendicular, straight line, parallel line, area, ratio and proportion, congruence, similarity, circle, curbs, oval shapes, parabola, midpoint to make different types of cloths. They use different types of tools such as image, table, cutting table, measuring tape, tailor square, trousers curbs, tailor's chalk, scissor etc. which make them easier to use mathematical concept. The tailor acquires mathematical knowledge through the practice of tailoring and society.

The very same one, Thapa, (2010) conducted the study on "A Study on the Mathematical Ideas Used by Slate Quarry Workers". The objectives were to explore the mathematical ideas used by slate quarry workers and to analyze how they acquire mathematical knowledge. The method of study was participant observation and interview. The study found that many conventional mathematical concepts are embedded in the selecting slate quarrying. The quarry workers used many mathematical concepts such as fundamental operations, number, measurement, straight line, parallel line, perpendicular, rectangle, square, triangle, trapezium, congruence, similarity, unitary method, sets etc. The research showed that the quarry acquires mathematical knowledge through experience and practice, practical activities and circumstance, observation, social and cultural interaction etc.

The above entire researcher intended to recognize the mathematical concepts of their selecting ethnic group and how they acquire mathematical knowledge. They used the participatory observation and interview as the methodology of data collecting. They chose constructivism theory as the theoretical base for their research. Grounded theory was the method of the data analysis process. The above entire review shows that the ethnic group used similar mathematical ideas of formal school in their own ways but they do not about formal mathematics. They acquire the mathematical knowledge from their society, culture, working process, observation, social interaction etc. these type of study helps to mathematics teacher to teach the reality base mathematics and students helps to understand the mathematical concepts in concrete form. These literatures give me ideas to select the suitable method, data collecting tools, data analysis procedures to my research.

There were so many research theses in various ethnic groups but I am not getting the research thesis about the mathematical ideas used in making stupa. Ethno-mathematics is used to express the relation between culture and mathematics. The stupa is related to culture (religion). Ethno-mathematics says that every ethnic group has their own mathematics.

Theoretical Literature Review

Theoretical literatures are those literatures, which provide theoretical knowledge and philosophical bases for research to researcher.

Constructivism. Constructivism means kind of consideration about the themes and built up a strong mental plan, so people have their own construction of mathematical object in a mathematical community.

All the people make their own form, belief, experiences. They construct new ideas from what they see, listen, and experience. They do not always use the taught method/ they all are not go to the formal school but use their own strategies to solve their problem on their own surroundings.

Constructivism is a post-structuralist psychological theory (Doll, 1993), one that constitutes learning as an interpretive, recursive, nonlinear building process by active learners interacting with their surround-the physical and social world. It is a psychological theory that describes how structures, language, activity, and meaning making come about, rather than are that simply characterizes the structures and stages of thought, or one that isolates behaviors learned through reinforcement. The challenge for educators is to determine what this new paradigm brings to the practice of teaching. Behaviorist framework preplan a curriculum by breaking a content area (usually seen as a finite body of predetermined knowledge) into assumed component parts-"skills"-and then sequencing these parts into a hierarchy ranging from simple to more complex. Assumptions are made that observation, listening to explanations from teachers who communicate clearly, or engaging in experiences, activities, or practice sessions with feedback will result in learning; and that proficient skills will quantity to produce the whole, or more encompassing concept (Bloom, 1956; Gagne, 1965) Also according to the Cook (1992), advocate the use of negotiation in the curriculum. When learner negotiation, ask the questions, and try hard to find the answer themselves, what they learn will be more meaningful to them. This means active environment in the problem the learner their learning can occur. Likewise, Fosnot(1989) defines constructivism according to four principles.

- Learning depends on what individuals already know.

- New ideas occur as individuals adopt and change their old ideas.
- Learning involves investing ideas rather than mechanically accumulating a series of facts.
- Meaningful learning occurs through rethinking old ideas and coming to new conclusions about new ideas which conflict with our old ideas.

These facts show that learning as active process. The individuals can change his/her old ideas from thinking and rethinking. The ideas of individual are modified/improved/upgrade by new construction.

At last, constructivism is a learning theory in which learning is both an active process and a personal representation of the world. In this theory knowledge is constructed from the experience and is modified through different experiences. Problem solving and understanding are emphasized in this theory.

Cognitive constructivism. Knowledge is constructed by learners and that any account of knowledge makes essential references to cognitive structures. Knowledge comprises the active system of intentional mental representations derived from past learning experience. Each learner interprets experience and in the light of their extant knowledge, their stage of cognitive development, their cultural background, their personal history and so far.

Cognitive construction is based on the work of developmental psychologist Jean Piaget. Piaget suggested that there are four main stages in the cognitive development of the children. These stages are divided on based on the age of the children. Nowadays Piaget's theory is famous by developmental theory. These four stages determined the child which mathematics can learn and can't learn that age. And these stages describe how children develop mathematical knowledge. Piaget's developmental theory is the major foundation of the cognitive constructivism.

The stage of cognitive growth of a person differs from another. All people cannot learn the same thing at the same stage. Some people can learn quickly and some are not. Cognitive development is an active process from the beginning to the end of life. Intellectual advancement happens because people at every age and developmental period look for cognitive equilibrium. cognitive equilibrium**,** a state of balance between individuals' mental schemata, or frameworks, and their environment.

Such balance occurs when their expectations, based on prior knowledge, fit with new knowledge (Beauchamp,2022). To achieve this balance, the easiest way is to understand the new experience through the lens of the preexisting idea.

Social Constructivism. Social constructivism is a type of constructivism developed by Lev Vygotsky, who emphasis on the society and develop his theory on the basis of social content of learning. Vygotsky's theory is very similar to the Piaget's assumptions about how children learn, but his emphasis on the society. Also in the Piaget's theory, the role of teacher plays the limited role where as in Vygotsky's theory the teacher plays the very important role in learning. Social constructivist does not stand by and watch children explore and discover. The teacher may guide students as their approach problem, may encourage them to work in group to think about issue a question and support them with encouragement and advices.

Social constructivism is based on the social phenomenon. People acquire the knowledge from their social practice through the experience, which they get from the adult activity and their environment. These assumptions allow the social constructivist epistemology to be developed from the two principles of radical constructivism, which are

- Knowledge is not passively received but actively built up by the cognizing subject.
- The function of cognition is adoptive and serves the organization of the experimental world, not the discovery of ontological reality, (Glasersfield,1998).

With the added assumption of the existence of social and physical reality it can extend these principles to elaborate the epistemological basis of social constructivism

- The personal theories, which result from, the organization of the experimental world must 'fit' constrains imposed by physical and social reality.
- They achieve this by a cycle of theory-prediction-test-failure-accommodation new theory
- These gives rise to socially agreed theories of the world and social patterns and rules of language use

- Mathematics is the theory of the form and structure that arises within language this provides the basis for a social constructivist philosophy of mathematics.

The social constructivist focus on actual production of scientific knowledge but not social factors and social practices influences scientific facts and its elements.

The most elements in this theory are the assumptions that human being rationalize their experience by creating a model of the social world and the way that it functions and the belief in language as the most essential system through which human construct reality.

Vygotsky (1978) states that cognitive growth occurs first on a social level, and then it can occur within the individual. To make sense of others and construct knowledge on such a social level allows learners to relate themselves to circumstances. Roth (2000) also states that the root of the individual's knowledge is found in their interaction with their surroundings and other people before their knowledge internalized. It means that the knowledge is existed in the society. First the children interact with his/her social environment then he/she taught him/herself according to their own environment. Then he/she make own sense about objects.

Thus society, which includes environment, languages and other adult practices, is the source of permanent knowledge for a child. By the similar way mathematical knowledge is also acquired from the social practices and adult practices.

Vygotsky's Social Constructivism. Vygotsky's theoretical discussion reveals the psychological perspective and describes about the insides of the individuals on the basis of social behaviors. The main concern of the theory is knowledge, human practice and society and culture. Vygotsky describes about learning out of the school environment and his concern related to learning in society and human behaviors.

Vygotsky describes a theory that "zone of proximal development (ZPD)" in this theory, the child needs some mediators like parents, teachers, and adults or peers to uplift his/ her knowledge from the knowledge that already exist with his/her. The children construction of knowledge is not from individual but from also the context and the interaction with the more knowledgeable others. Schitzi (2002) describes Vygotsky's zone of proximal development. He says that it is the difference between

the child's capacity to solve their problem on his/her own and his/her capacity to solve them with assistance. In other words, the actual developmental level refers to all the functions and activities that a child can perform in dependently. On the other hand, the ZPD includes all the functions and activities that child or a learner can perform only with the assistance of or someone else. The person in this scaffolding process providing non-instructive intervention could be an adult such as parents, teacher, and caretaker.

Vygotsky stresses that child construct the knowledge from maturation and culture. Here external cultural knowledge is internalized with the help of their parents and the conversation of community. So the psychological functions in these children originate in interaction with outer or intrapersonal and only later become interpersonal.

In the context of studying the behavior of the Artisans, social constructivism, philosophy of mathematics argues the mathematical practice begun from the society and social activities. It means Artisans have mathematical knowledge. So the Vygotsky's theory of ZPD will helpful to prepare the theoretical frame to understand the Artisans mathematical thinking and their behavior in the society and their working field. I will borrow the theoretical ideas from ZPD that human behavior is determined in the form of language, cultural situations, communication, and social factors which influence the human behavior.

Conceptual Framework

From the above discussed point of views in related literatures, mathematical concepts practices in making stupa may be in different form. Such as numerals, measuring system, geometrical form etc. These concepts can be seeking in the artifacts, their making process, and their using tools.

Conceptual framework devised through the literature studies facilitated to attain research objectives, get the answer of the research questions and carry out the research work as a whole smoothly (Acharya, 2015). A conceptual framework is a representation, either graphically or in narrative form, of the main concepts variables, and their presumed relationship with each other (Punch, 2005). In the figure below use of mathematics in making stupa is the main issue in this study. The framework

constitutes the study of cultures and mathematics that is, ethno-mathematics. The ethno mathematics links the school mathematics and is applied form of mathematics. These core frameworks bind the main process of Constructivism which is composed of cognitive constructivism, social constructivism and Vygotsky's social constructivism. These are the theories for the Theoretical literature review. On the basis of these theories Interview, observation and document analysis are done as the tools of data collection. The data collected is analyzed and interpreted to conclude the findings.

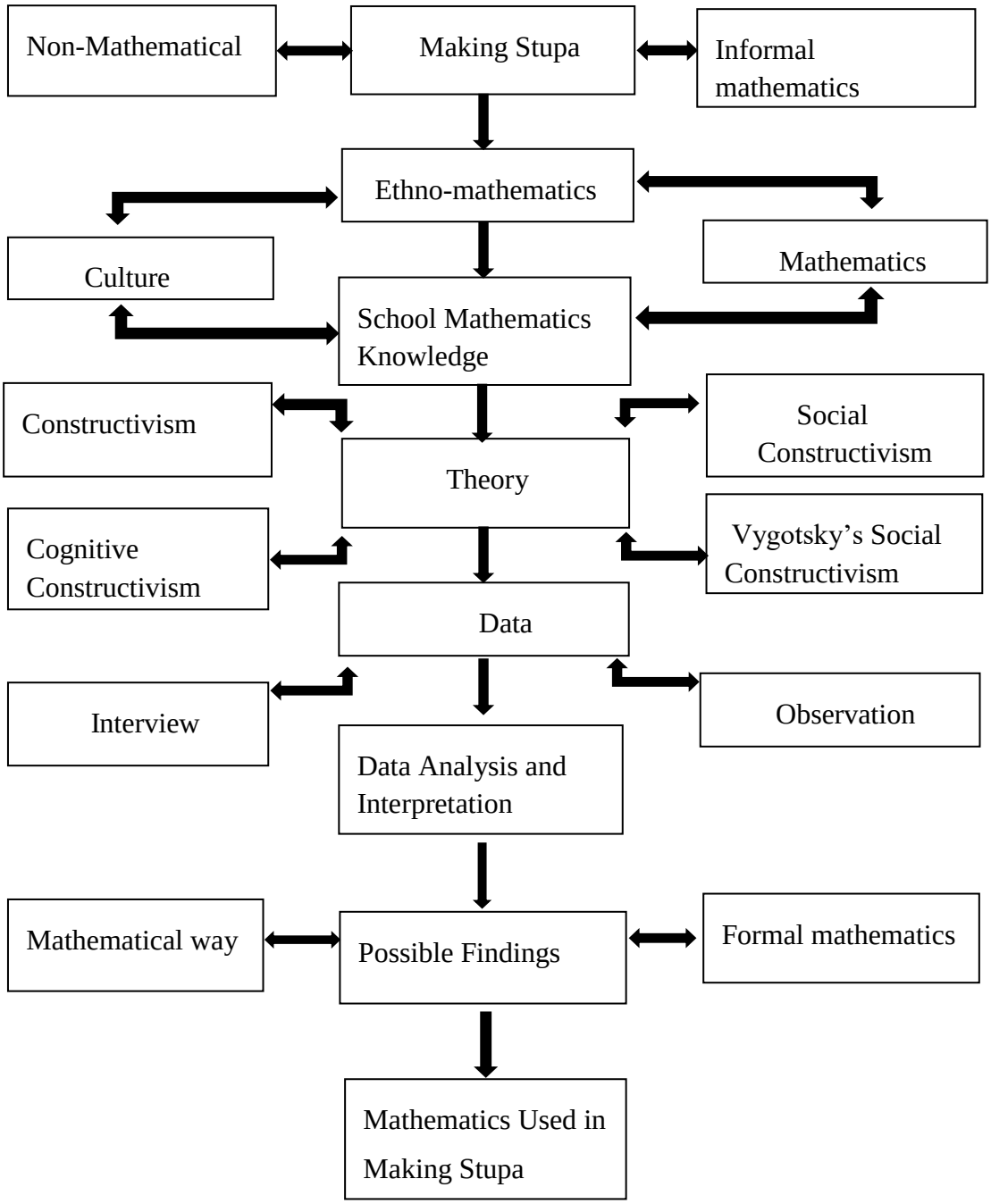


Figure 2.1 Conceptual Framework

Chapter Summary

The review is made in terms of what is ethno-mathematics, importance of mathematical knowledge in making stupa especially ‘Mahabodhi’ and the relations of ethno-mathematics with formal mathematics education at school. Furthermore, the chapter covered the theory of ethno-mathematics that has guided my ideas and views for this research. In the same way, I reviewed some previous research studies related to my study areas that have been carried out so far. The empirical review consisted studies carried out in Nepal and outside country pertaining to my topic. I then drew the research gap for my study and presented the conceptual framework. This chapter covered different views about importance of ethno-mathematics knowledge and experiences in teaching mathematics at school.

Chapter III

Methodology

This chapter describes how the study was conducted to fulfill the objective of the study. Methodology deals with the research design, population and sample, data collection tools, reliability and validity of tools, data collection process, data analysis, and interpretation process. Richard (2004) describe more precisely this section describe action to be taken to investigate a research problem and rationale for the application of specific processes or techniques used to identify, select, process and analyze information applied to understanding the problem, thereby, allowing the reader to critically evaluate the study's overall validation and reliability. This section of research answers two main questions: How was the data collected or generated? And how was it analyzed?

For solving the statements of problem qualitative paradigm of the research was used. Qualitative research involves several methods of data collections, such as focus groups, field observation, in-depth interviews, and case studies (Roger D. Wimmer and Joseph R. Dominick, 2015).Qualitative research methods were developed in the social sciences to enable researchers to study social and cultural phenomena. Qualitative research is about person's life, stories and behavior. Qualitative research is based on phenomenological paradigm, which uses a variety of interpretive research methodologies. According to(Kumar, 2011), the main focus in qualitative research is to understand, explain, explore, discover and clarify situations, feelings, perceptions, attitudes, values, beliefs and experiences of a group of people.

The study was an ethnographic, a qualitative research in nature. This study explored mathematical concepts used in making stupa. This study was carried out on the basis of field work or participant observation and interview. To attain objectives of the study the researcher followed certain research procedure. For proper conduction of this qualitative research, I used general inductive approach which is a methodology for gathering and analyzing data systematically and simultaneously.

Research Design

This study is an ethnographic study using emic prospective of mathematical concepts practices in making stupa. This study was carried out on the basis of qualitative research method. Especially, it is ethnographic study of stupas with group of Artisans.

Study Site

Two sites for the study was selected in purpose. Stupa Handicrafts Company, Gwarko, lalitpur and Copper Carbine Handicraft, Swayambhu, Kathmandu were the study sites.

Selection of Respondents

This study was based on qualitative research. A sample is small proportion of the population for observation and analysis. The purposive sampling techniques was used for the selection of respondents. Total of five respondents were selected from two companies among which three were selected from Stupa Handicraft Company and two from Copper Carbine Company. The respondents actively involved in the research by giving their professional opinions.

The details of the respondents are presented below:

Table 3.1 Details of the respondent

Name of Company	Name	Age	Working Experience	Education
Stupa Handicraft Company, Lalitpur	Respondent A	49	25 years	Under SLC
	Respondent B	44	15 years	Under SLC
	Respondent C	32	10 years	SLC
Copper Carbine Company, Kathmandu	Respondent A	52	25 years	Under SLC
	Respondent B	30	8 years	Under SLC

Sampling Procedure

This study was an ethnographic study of stupa with a group of Artisans. A small proportion of the population was selected for observation and analyzed. The target population was selected purposefully as a sample for the study.

Instruments of Data Collection

According to Khanal (2073) in an ethnography research the approach to gathering data is to i) observe the culture for weeks, months even years; ii) interact with and interview member of the culture; and iii) analyze documents and artifacts. Characteristics of ethnography involves extended participant observation, long time at the site, collection of large volume and openness (Creswell, 2012) It needs close involvement of researcher with the person/objects/sites/activity which is relevant to the aim of study. Data were collected through photos, videos and voice recorder which were later analyzed. I collected data from following tools and techniques.

Observation. In experimental research, observation is most frequently the method of choice of behavior modification studies that frequently use single subject research designs. Observation is most often used in small sampled subjects which may be participant and non-participant. Participant observation is that in which the observer is familiar and participate with the subject of the study. This study was carried out with close observation with myself being an apprentice of the Artisans which helped me to gather the information and data. Whole process of making stupa from planning, sketching, molding, framing to construction was observed and each steps with every details was noted.

Interview. Interview is collecting information from person. The meaning of interview as given by Webb and Webb is conversation with a purpose. Interview help us to find out what we can't be directly observed, for example feelings, thoughts and intentions. Instead of writing the response, the subject or interviewee gives the needed information orally in to face-to-face manner. Most of this discussion focuses on qualitative research. Interview helps to get information which they are not obtained from observation. The advantage of interviewing is that the interviewee can explain more explicitly the investigation purpose and just what information he/she wants. If the subject misinterprets the questions, the interviewer may follow it with a clarifying question. At the same time, he/she may evaluate the sincerity and insight of the interviewee.

For this study, five artists having keen knowledge on stupa making and Buddhism were interviewed. Three from Stupa Handicrafts Company, Gwarko,

Lalitpur and two artists from Copper Carbine Handicraft, Swyambhu, Kathmandu was conducted.

Data Analysis Procedures

I analyzed the data by using general inductive approach. According to Thomas (2006) following strategies and principles are underlying in the general inductive approach.

- Data analysis is guided by the evaluation objectives, which identify domains and topic to be investigated.
- The primary mode of analysis is the development of the categories from the raw data into model or framework.
- The finding result from multiple interpretation made from the raw data by the evaluator who code data.
- Different evaluator may produce finding that are not identical and that have non overlapping components.
- The trustworthiness of findings derived from inductive analysis can be assessed using quality standard (p.239- 240)

Firstly, I gathered the raw data by using above mentioned tools then I organized the raw data through a process known as inductive coding. Inductive coding begins with close readings of raw data and consideration of the multiple meanings that are in the raw data. Through inductive coding, I reviewed the raw data, make notes. I read the materials multiple times. After that I transcribed the notes and headings into a coding sheet. In the next steps I categorized the raw data and combine the similar data to reduce category. Through this process I analyzed the data.

Quality Standard

After completing the construction of the research tools, it is necessary to maintain quality standard. For maintaining quality, following parameter were considered.

Triangulation. Triangulation was used to illuminate some ways to tests or maximize the validity and reliability of the data. Triangulation is the powerful

technique that facilitates validation of data through cross verification from more than two sources. Triangulation is typically a strategy for improving the validity and reliability of qualitative research. In this process, by combining multiple observers, theories, methods, and empirical materials researcher can hope to overcome the weakness or biases and the problem that come for single method, single observer, and single theory study. Triangulation is a method of cross-checking data from multiple sources to search for regularities in the research data.

In this research data triangulation was used which involves times, space, and persons. Researcher collected data at different points in time. Also data was collected more than one site and from more than one level of person that is from two groups. In methodological triangulation I used more than one method to collect data, such as interview and participant observation. Thus triangulation and export judgment was used for maximizing validity and establishing the reliability of data.

Credibility. This concept replaces the idea of internal validity, by which researcher seek to establish confidence in the truth of their finding. To maintain the credibility of my research, I tried to spend as much time as the observation needed and engaged with different people with their work. After getting information I wrote notes, I asked similar types of question to the people from different company and try to find real practices from this information.

Conformability. Conformability refers to the quality of the results produced by an inquiry in terms of how they are supported by informants who are involved in the study and by events that are independent of the inquirer. It also referred as audit trail which allows any observer to trace the course of the research step by step via the decision made and procedures described. For conformability member checking, interpretation checking, debriefing was done.

Transferability. Transferability replaces the concept of external validity. This criterion refers to the applicability of findings is on context (where the research is done) to other contexts or settings (where the interpretation might be transferability). To maintain transferability, I expanded mathematical practices found in making stupa briefly. I tried to capture most of the scenarios by using tick description of observation, interview, and document analysis.

Chapter Summary

In this chapter, I discussed the methodologies applied in this research that included methods, sources and procedures of data collection and quality standard. I presented the description and reason for choosing ethnography as a paradigm as my research as my research method. Interviews and observations were the two ways to depict the information from the participants. The selection of research sites and participants and the quality standards have been discussed in the chapter.

Chapter IV

Analysis and Interpretation

This research entitled “Use of mathematics in making stupa” is an ethnographic study with the use of qualitative research approach. Data related to the use of mathematics in making stupa has been collected through rigorous observation and interviews in two study sites. The study primarily focused on to findings based on the two objectives. Findings and its analysis have been discussed thoroughly below.

Structure and Orientation of Stupa

Stupa are established with their main orientation lines preceded by equal number of units on both right and left sides and upper and lower sides from the central point in order to make the stupas proportionate. Irrespective of the size, stupa has 20 equal units on both the right and left sides of the central vertical axis totaling 40 equal parts. Similarly, 32 equal units are made in both the upper and lower sides of the central horizontal axis, totaling 64 equal units from the bottom to top.

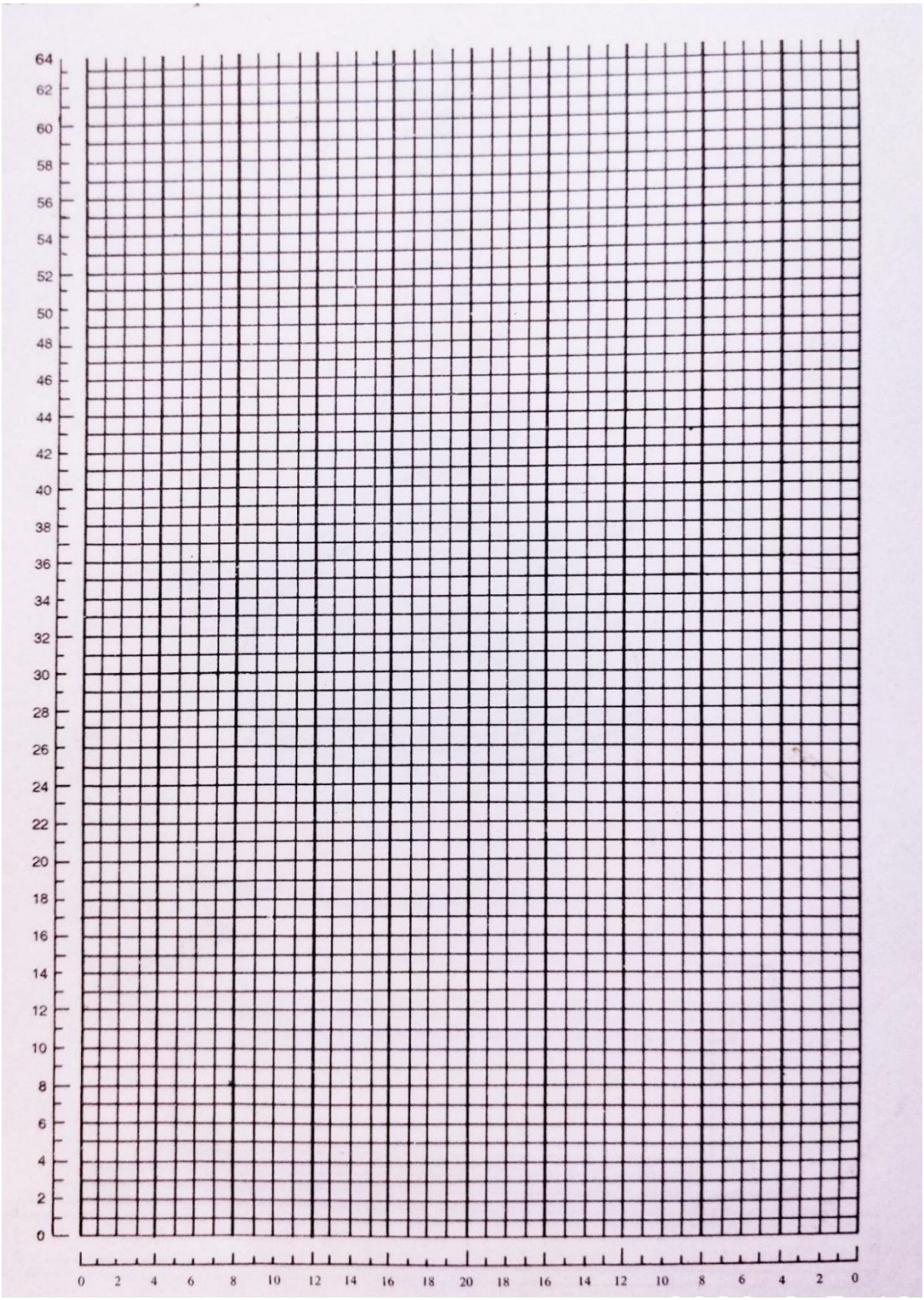


Figure 4.1 Main Orientation Lines

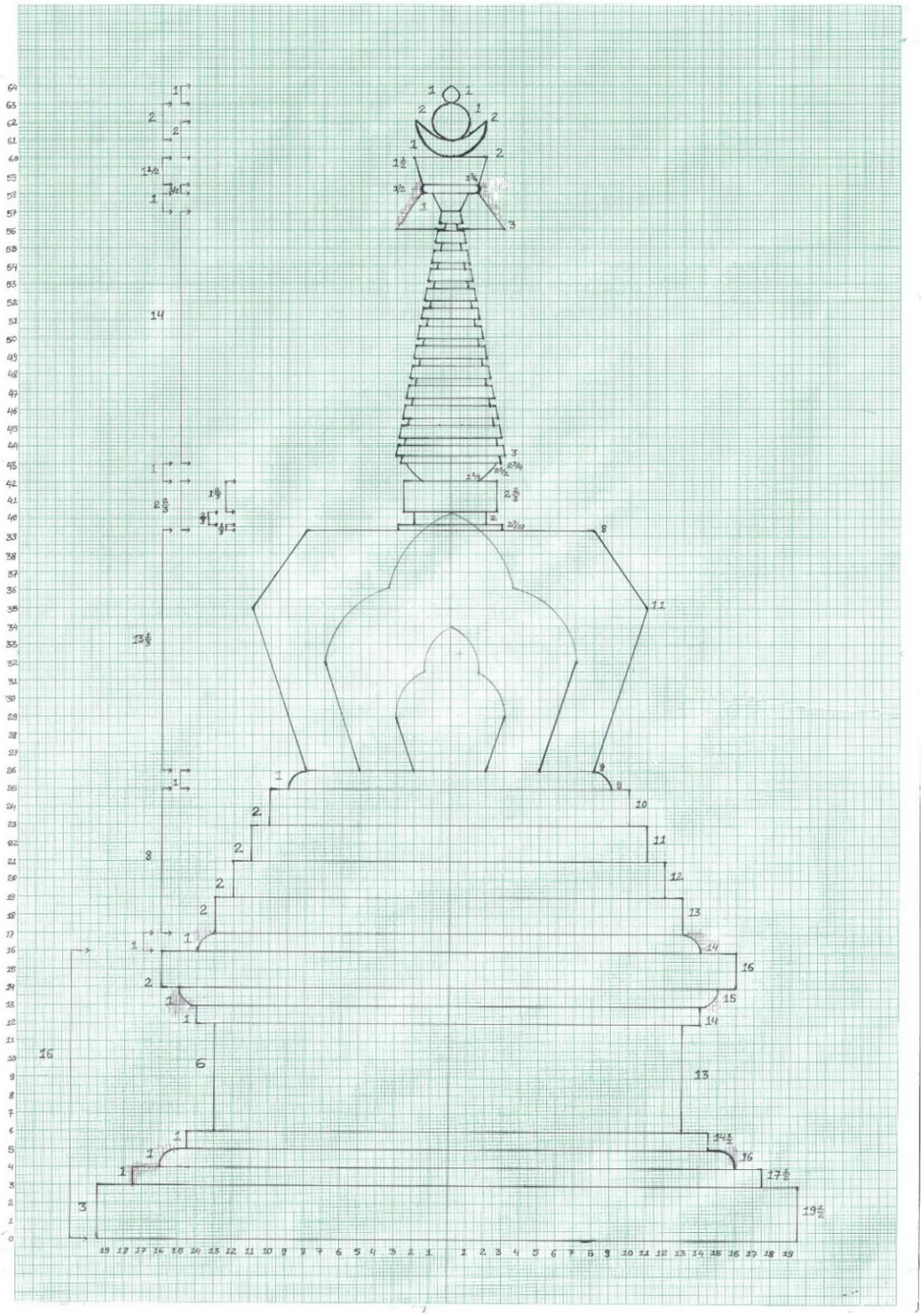


Figure 4.2 Stupa on Graph

Table 4.1 Structural components of Stupa with the proportion

Structural components	Proportion for the Stupa of Enlightenment	
	Height (In Small Unit)	Width (In Small Unit)
Spherical Pinnacle	1	1
Sun	2	2
Moon	1	4
Cover of umbrella	$1\frac{1}{2}$	$3\frac{1}{2}$ to 4
Umbrella	1	6 to 4
Formula of compassion	1	1 to 2
13^{th} wheel 13 wheel 1^{st} wheel	14	1 6
Lotus Supporting Umbrella	1	3 to 5
Harmika Harmika Base Harmika Base Supporter	$1\frac{2}{3}$ 2/3 1/3	$5\frac{1}{3}$ 4 $5\frac{4}{5}$
Vase shoulder Vase belly Vase Vase Root	$13\frac{1}{3}$	16 22 16
Vase Base	1	18
4^{th} step	2	20
3^{rd} step	2	22
2^{nd} step	2	24
1^{st} step	2	26
Ten Virtues Base	1	28
Cap or Big Edge	2	32
Small Edge	1	30
Cornice	1	28
Main-facade	6	26
Three Staircases (1^{st}, 2^{nd}, 3^{rd})	3	35,32,29
Plinth	3	39

Components of the Stupa

Tibeto- Buddhist stupa comprises three main structural components; the Lion Throne, the intermediate section, and the upper section.

The Lion Throne *(Singhaashan)*

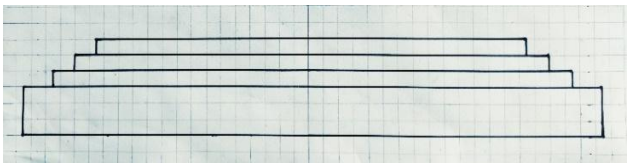
The Lion Throne is the lower section of the stupa, which consists of six symbolic structures from the ground plinth up to the frame. The study showed that the structural shape of the Lion Throne is perfectly square. Eight auspicious symbols are carved on the four cardinal surfaces of the Lion Throne. The animals are usually represented by two figures each of a lion, *garuda*, horse and peacock. In practice interviewees shared that lion are carved in most of the cases.

Use of Mathematics in the Lion Throne

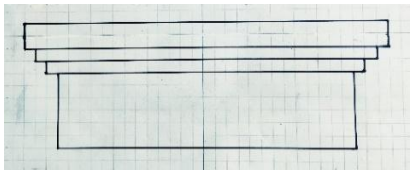
The foundation of the lion throne also called as Plinth *(Taloko Bhag)* is three small units in height. Next is followed by three staircases each being size of one unit. The staircases are followed by main Façade which is six units in height. The Façade is then followed by Cornice, Small Edge and Big Edge simultaneously one above another. Cornice and Small Edge are one unit and Big Edge is two units in height.

In breadth the basement or plinth is nineteen and a half units each on both the right and left sides. The first or bottom staircase is seventeen and a half units each at the right and left. The second or middle staircase, on both the right and left sides, is sixteen units each. The third or top most one is fourteen and a half units wide on both the right and left side. The main facade is thirteen small units each at the right and left. Starting from down upward the cornice, the small edge and the big edge, on both the right and left of the axis, fourteen, fifteen and sixteen small units each, respectively.

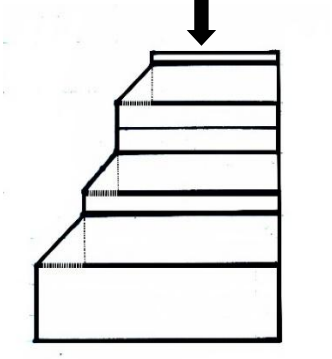
The faces of components of the Lion Throne is in rectangle shape whereas its Floor and Ceiling is in square shape. The artisans use measuring tape to measure the height and width and uses pivot square tool to measure exact 90^0 angle. The concept of parallel lines is used to make these components symmetrical among each other.



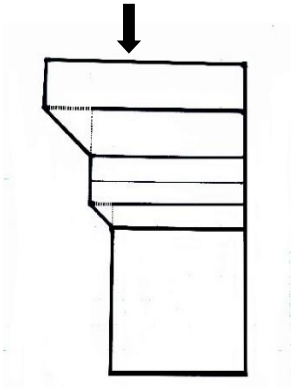
Lower section of Lion Throne



Upper section of Lion Throne



Reference piece for measurement



Reference piece for measurement

3 D structure of Lower section

3D structure of upper section

Complete 3D Structure of Lion Throne

Figure 4.3 Process of making Lion Throne

Process of making Reference for Lower Section of Lion Throne

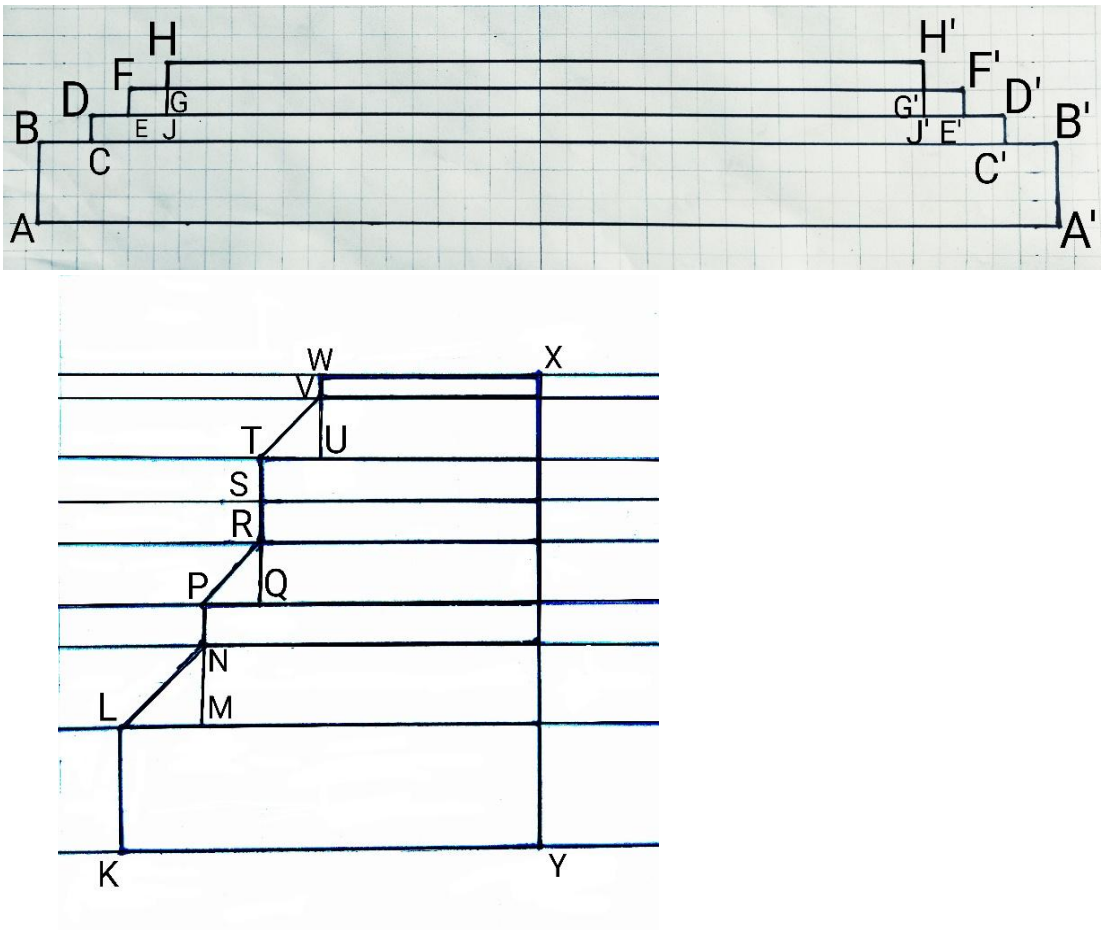
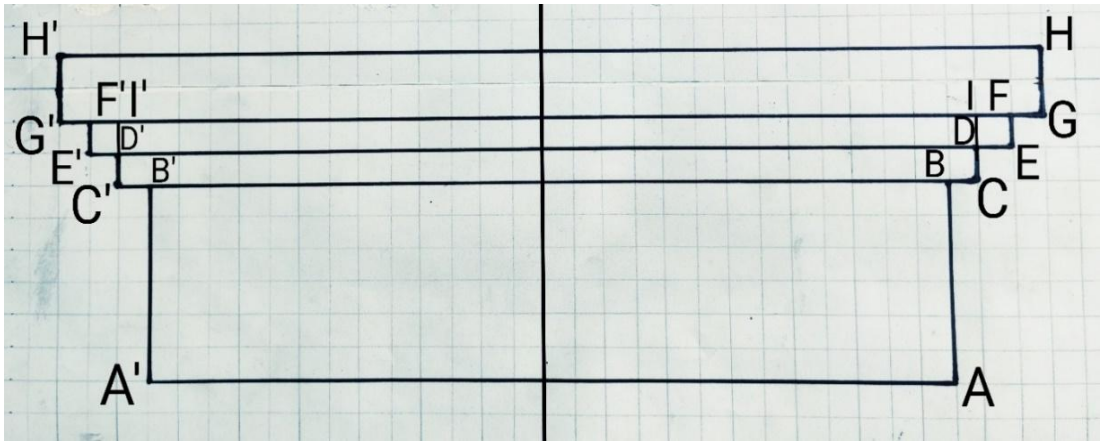


Figure 4. 4 Process of making Reference for lower section of Lion Throne

- In the figure, eight parallel lines are drawn as AB=KL, BC=MN, CD=NP, DE=QR, EF=RS, GH=ST and FG=UV.
- Lower most line is taken as a base line where Y and K are marked and the distance between them is half to the distance of AA'.
- KL equal to AB is drawn and is extended to reach the next parallel line. The point of touch is named L.
- LM=MN which is equal to BC is drawn and L and N are joint.
- MN is extended to reach the next parallel line and the point of touch is named Q where CD=NP.
- PQ=QR which is equal to DE is drawn and P and R are joint.
- QR is extended till it reaches next two parallel lines and point of contact is named S and T where EF=RS, GH=ST.
- TU=UV which is equal to FG is drawn and T and V are joint.

- UV is extended as desired to adjust the upper section of the Lion Throne where the point of contact is called W.
- W is extended half the length of HH' horizontally and the end point is named X and X and Y are joint.
- Polygon KLNPNQRSTVWXY is taken as a reference to make left lower section of one face of the Lion Throne. The same process is repeated to make its right portion.
- The same process is repeated to make remaining three faces of the lower section of the Lion Throne.
- These four faces are joint to make 3D structure of the Lion Throne.

Process of making Reference for Upper Section of Lion Throne



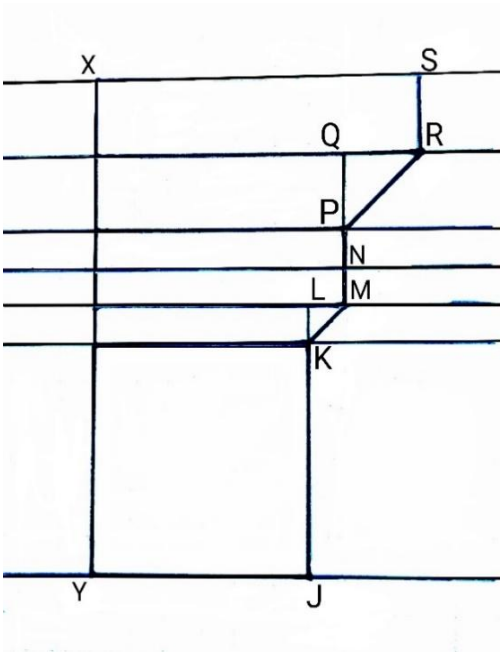


Figure 4.5 Process of making Reference for Upper Section of the Lion Throne

- In the figure, seven parallel lines are drawn as AB=JK, BC=KL, CD=MN, EF=NP, IG=PQ, GH=RS.
- Lower most line is taken as a base line where Y and J are marked and its distance is half to the distance of AA'.
- JK equal to AB is drawn and is extended to reach the next parallel line. The point of touch is named L.
- KL=LM which is equal to BC is drawn and K and M are joint.
- CD= MN from point M and EF=NP from point N are drawn. MP is extended to reach the next parallel line and the point of touch is named Q.
- PQ=QR which is equal to IG is drawn and P and R are joint.
- RS equal to GH is drawn.
- XY is drawn where XS is half to the length of HH'.
- Polygon JKMNPRSXY is taken as a reference to make right upper section of one face of the Lion Throne. The same process is repeated to make its left portion.
- The same process is repeated to make remaining three faces of the upper section of the Lion Throne.
- These four faces are joint to make 3D structure of the Lion Throne.
- Vertical height KL, LM, NS, TU and VW represent height of each step whereas slight height MN, ST and UV represent the breadth of each step.
- AB represents the main façade and two lion designs are crafted in each four faces. *Bishwo Bajra* is crafted in between two lion design.
- 16 designs are crafted on step CD (Cornice), lotus design is crafted on NP (Small Edge) and 16 designs are crafted on Big Edge.

The Intermediate Section

The Intermediate Section or in architectural terminology the later extremity comprises six symbolic structures from the base of ten-virtues *(Chartalleko Pema)* up to the Harmika*(Charpate).* Structurally the base ten virtues represent the foundation of the main structure of the stupa which is square in shape and has to be inscribed with the lotus petal *(Pema)* designs. It is also called the "seat of ten-virtues" Upon this, there is a flight of four steps which shorten progressively towards the top while

maintaining equal height. In the case of other stupas, the steps are generally square, circular, octagonal or projectional in shape.

The Vase-Support is circular in shape and has to be inscribed with lotus petal designs. Upon it stands the Vase-Shaped Dome, which broadens gradually from the Vase-Base up towards the Vase-belly, until it reaches its full width which is equal to that of the third step. From here, it curves or goes straight inwards until it becomes equal in width to the vase-root. The dome is topped by the Harmika-Base and the Harmika, which are square in shape.

The intermediate Section represent the human body. To be given a rough account, the Harmika is the face, the Harmika Base is the neck, the Vase is the body, the flight of four steps represent the lower part of the body in a cross-legged posture, and the area above Thirteen-wheels symbolize the protrusion of the head. However, an exact measurement does not occur. The base of ten virtues and below that are not to be counted as the proportion of the body.

Use of Mathematics in Intermediate Section

The ten virtuous-base is one unit in height. From first step to fourth, each is of two units in height. The vase base is of one unit in height. The height of the vase is thirteen and one third unit. The Harmika base support has height of one third unit. The Harmika Base has height of two third unit and Harmika has one and two third unit. The breadth can also be stated as below. Starting from the ten virtuous-base, it has breadth of fourteen units from the Centre to right and left. From first step to fourth step each has breadth of thirteen, twelve, eleven and ten units respectively from Centre to both right and left direction. At each level, the unit has reduced by one unit. The vase base has breadth of nine units at the base tip with its edges curved to form lotuses at top of eight units. The base tip of the vase thus has radius of eight units. The radius keeps on advancing to eleven units up to the height of nine units and then recedes to eight units up to four and one third unit. The Harmika base support has breadth of two and nine tenth unit. The Harmika base has two-unit breadth and the Harmika has two and two third unit breath at right and left.

Ten virtuous-base *(Char Talle Ko Pema)* and Four Steps *(Char Talle)*

The First Step Symbolizes the four close mindfulness.(1) The close mindfulness of body (2) The close mindfulness of feeling (3) The close mindfulness of mind, and (4) The close mindfulness of wisdom.

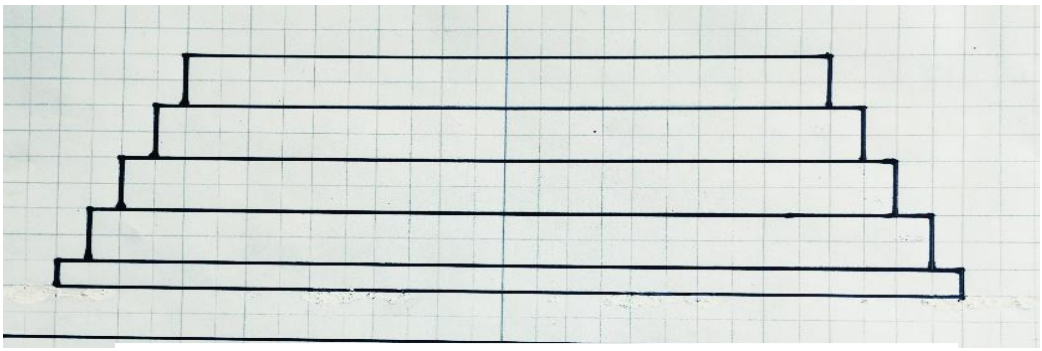
The Second Step symbolizes the four perfect abandonments. (1) Effort to abandon the non-virtues that have arisen, (2) Effort to prevent the non-virtues that have not yet arisen, (3) Effort to produce the virtues that have not yet arisen, and (4) Effort to retain the virtues that have already arisen.

The Third Step Symbolizes the four stages of miraculous powers. (1) A miraculous power possessed of compositional factor renouncing an aspiration of meditative concentration of desire, (2) A miraculous power possessed of compositional factor renouncing a meditative concentration of mind, (3) A miraculous power possessed of compositional factor renouncing a meditative concentration of effort, and (4) A miraculous power possessed of compositional factor renouncing a meditative concentration of analysis.

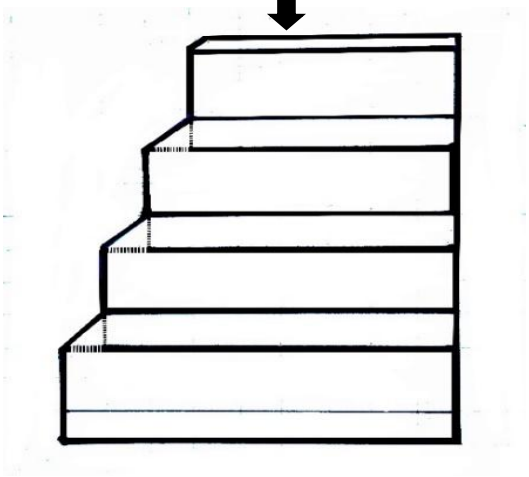
The Fourth step symbolizes the five moral faculties. (1) Moral faculty of faith (2) Moral faculty of effort (3) Moral faculty of mindfulness, (4) Moral faculty of meditative concentration and (5) Moral faculty of wisdom.

The Ten virtuous-base is one unit in height. From first step to fourth, each is of two units in height. Starting from the ten virtuous-base, it has breadth of fourteen units from the Centre to right and left. From first step to fourth step each has breadth of thirteen, twelve, eleven and ten units respectively from Centre to both right and left direction. At each level, the unit has reduced by one unit.

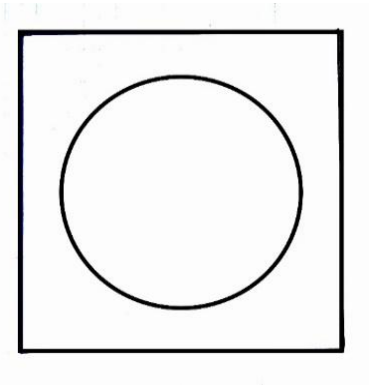
The faces of components of these components are rectangle in shape. Its base is square in shape. Ceiling is square at the periphery and a circular whole is made at inner section to hold the Vase. The artisans use measuring tape to measure the height and width and uses pivot square tool to measure exact 90^0 angle and use compass to make circular whole at the ceiling. The concept of parallel lines is used to make these components symmetrical among each other.



Graphic Design of Ten Virtuous-Base and Four Steps



Reference piece for measurement



Reference piece for measurement for the ceiling

Complete structure of Four Step

Figure 4.6 Process of making Four Steps

Process of making Reference for Four Steps

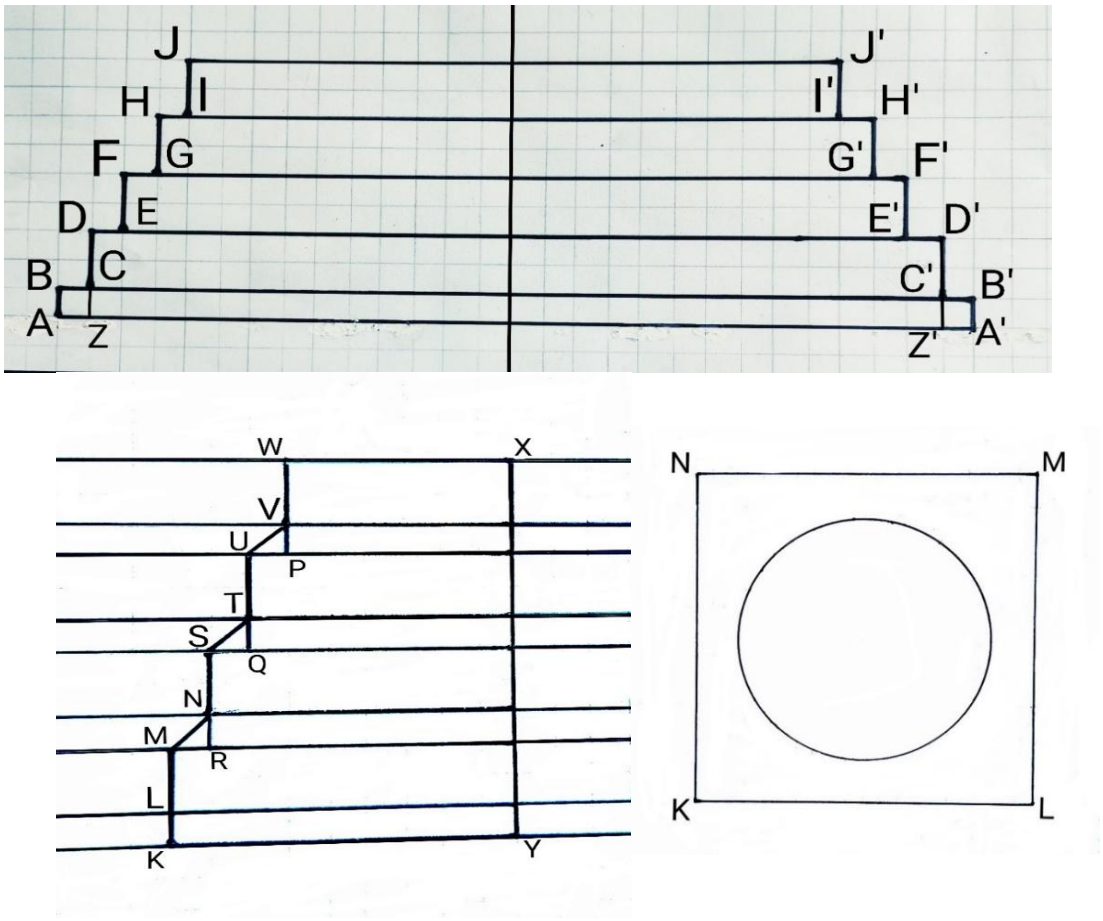


Figure 4.7 Process of making Reference for Four Steps

- Nine parallel lines are drawn where AB=KL, CD=LM, DE=RN, EF=NS, FG=QT, GH=TU, HI=PV and IJ=VW.
- The lowermost line in the plane figure is taken as a base line where a point K is marked.
- KL equal to AB is drawn from K.
- KL is extended to upper next parallel line and the point is named M.
- Two lines MR and NR both equal to length BC is drawn and M and N is joint.
- RN is extended to upper next parallel line and the point is named S.
- Two lines SQ and QT both equal to length FG is drawn and S and T is joint.
- QT is extended to upper next parallel line and the point is named U.

- Two lines UP and PV both equal to length HI is drawn and U and V is joint.
- PV is extended to upper last parallel line and the point is named W.
- Upper most and lower most parallel lines are joint through points X and Y to get left portion of Four step. Polygon KLMNSTUVWXY is the final reference left portion of Four Steps. Right portion with the same shape and size to that of left person is made. These two portions are then joint to make full structure of on face Four Step.
- Copper sheet same in shape and size of paper Four with polygon Step is cut.
- The same process is repeated to remaining three faces of the Four Step.
- Theses copper faces are folded and joint to make 3D structure of the Four Step.
- Lotus petal design is crafted on KL step and vertical height LM, NS, TU and VW represent height of each step whereas slight height MN, ST and UV represent the breadth of each step. Sixteen design is crafted on each step with total of 64 designs on four steps.

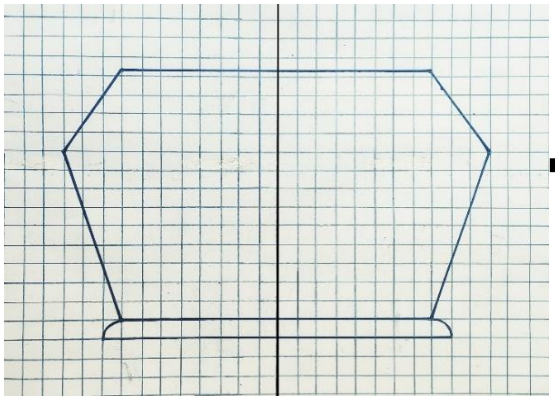
Vase-Base *(Bhumbako Pema)* and Vase *(Bhumba)*

The vase-base symbolizes the five moral powers. (1) The moral power of faith), (2) The moral power of effort, (3) The moral power of mindfulness (4) The moral) power of meditative concentration, and (5) The moral power of wisdom.

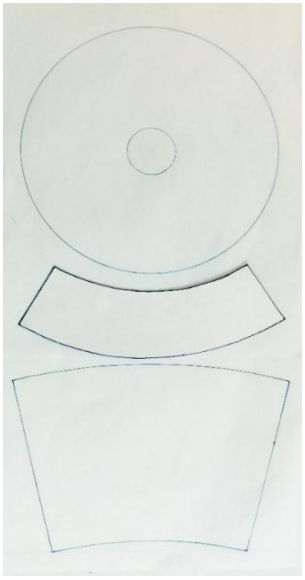
The vase symbolizes the seven factors of enlightenment (1) The factor of enlightenment to the perfect mindfulness, (2) The factor of enlightenment to the perfect dharma, (3) The factor of enlightenment to the perfect joy, (4) The factors of enlightenment to the perfect effort, (5) The factor of enlightenment to the perfect suppleness, (6) The factor of enlightenment to the perfect meditative concentration and (7) The factor of enlightenment to the perfect equanimity

The Vase Base is of one unit in height. The height of the vase is thirteen and one third unit. The vase base has breadth of nine units at the base tip with its edges curved to form lotuses at top of eight units. The base tip of the vase thus has radius of eight units. The radius keeps on advancing to eleven units up to the height of nine units and then recedes to eight units.

The concept of circle is used so as to make the Vase and Vase Base circular. The radius of nine units and eight units is taken for the Vase- Base and the Vase. The ceiling is circular having eight unit radius. Four same size sheets of copper equal to the size of the vase in graph are cut and bonded to each other. Then by hammering they are made circular and for the top circular sheet of size 8 units is cut and attached to the Vase. 8 *Chhepu* designs are kept in the vase. To make it more attractive various designs are further carved.



Vase Base and Vase on graph



Reference piece
for measurement

3D structure of Vase Base and Vase

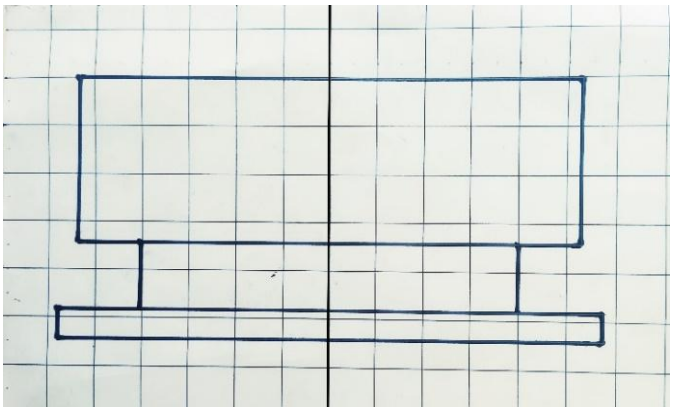
Figure 4.8 Process of making Vase Base and Vase

Harmika *(Charpate)*

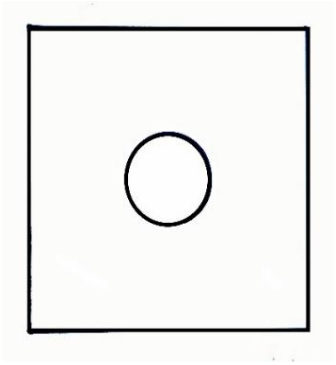
The Harmika symbolizes the Eightfold Noble paths (1) Right view (2) Right thought), (3) Right speech Right action), (5) Right livelihood, (6) Right endeavor, (7) Right mindfulness (8) Right meditative concentration.

The Harmika Base Support has height of one third unit, the Harmika Base has height of two third unit and The Harmika has one and two third unit. The Harmika Base Support has breadth of two and nine tenth unit. The Harmika Base has two-unit breadth and the Harmika has two and two third unit breath at right and left.

The faces of components of these components are rectangle in shape. Its base is square in shape. Ceiling is square at the periphery and a circular whole is made at inner section to hold the Lotus Supporting Umbrella. The artisans use measuring tape to measure the height and width and uses pivot square tool to measure exact 90^0 angle and use compass to make circular whole at the ceiling.



Harmika Design on Graph



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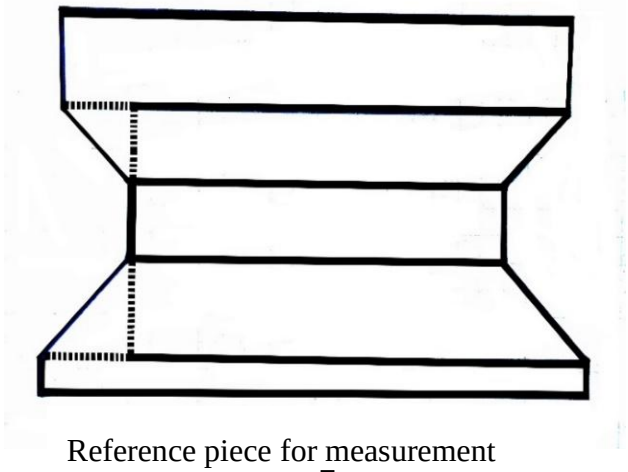


Reference piece for measurement

Ceiling of Harmika

3 D structure of Harmika

Figure 4.9 Process of making Harmika

Process of Making Reference for Harmika *(Charpate)*

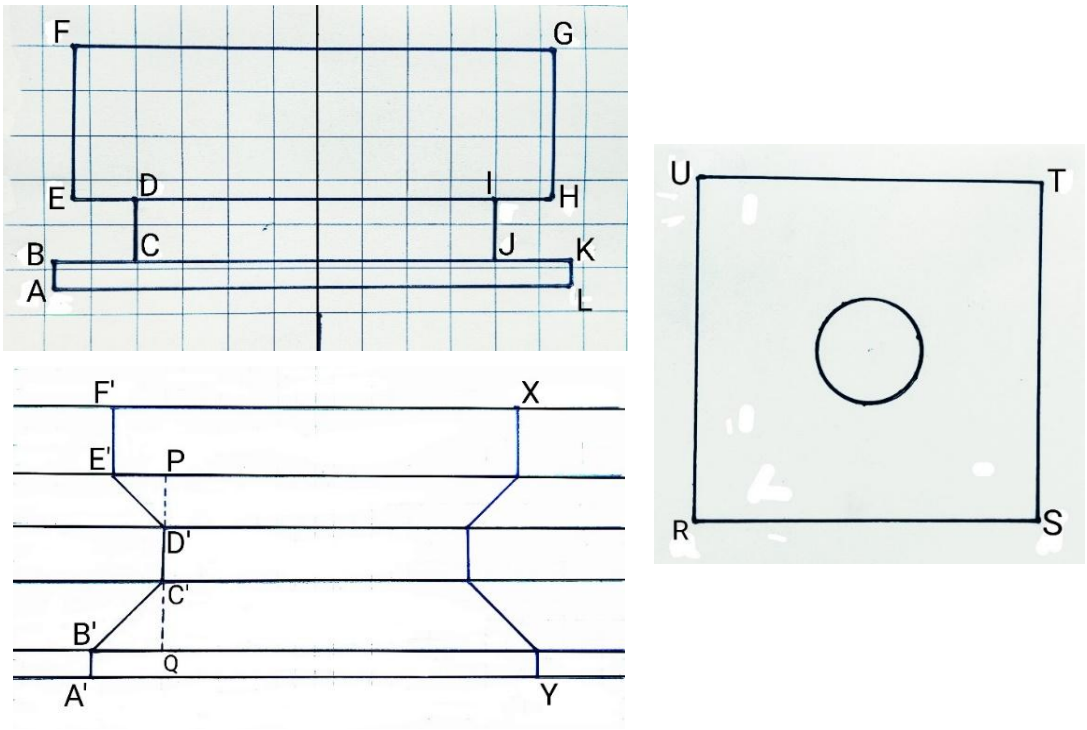


Figure 4.10 Process of Making Reference for Harmika

- Six parallel lines are drawn where, AC=MO, CE=OY=YQ, EG=QS, GI=SA'=A'U, IK=UW.
- Number of parallel lines are changed based on the design of the Harmika.
- Point M and point O and point N and point P are joint.
- DY and QY both equal to CE are drawn and O and Q are joint.
- YQ is extended to point S and further to A'.
- A'U equal to SA' is drawn and point S and U is joint
- Point U and W are joint ie, IK=UW.
- Marks are drawn where AB=MN=CD=OP, EF=QR=GH=ST, IJ=UV=KL=WX.
- The same process is repeated on the next face.
- All the above steps are the process of converting plane figure to the reference sheet.
- Four copper sheet is cut equal to the shape and size of the reference sheet.
- These copper sheets are folded on the parallel lines and are joint to make the 3D structure of the Harmika.

- Copper sheet with the size KL=WX is cut for the ceiling of the Harmika. A circular hole is made to hold Lotus Supporting Umbrella.

The Upper Section

The upper section consists of structures from the Lotus Supporting-umbrella *(Terha Talle Muni Ko Pema)* up to the Spherical Pinnacle *(Tara)*. The Lotus Supporting-umbrella is inscribed with lotus petal *(Pema)* all along its circumference. Upon this, there is a tier of thirteen wheels in the shape of thirteen disks or rings that taper off in height and circumference towards the topmost wheel. All the wheels are of equal height.

Over the thirteenth wheel rests the structure of Formula of Compassion *(Terha Talle Mathi Ko Pema)*. It is in the form of the offering cup. The Formula of Compassion is covered by the Umbrella *(Tallo Jhul)*. The moon *(Jun)* stands upon the Formula of Compassion which is in the shape of a crescent. Sun *(Gham)* stands over the Moon. The radius of sun is a bit smaller than that of the Moon. The Spherical Pinnacle *(Tara)* at the topmost positon above the Sun.

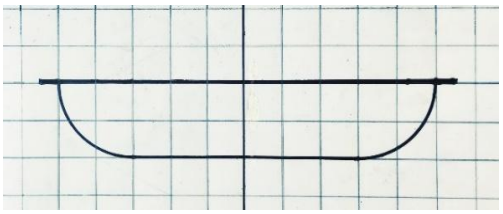
Use of Mathematics in the Upper Section

The first component is Lotus supporting umbrella. The lotus supporting umbrella has a height of one unit. It is a bowl shaped with its base tip of radius one and half unit and advances to two and half unit from the Centre. The thirteen wheels has total height of fourteen units in a cone shape tapering to the top. The total cone with wheels is divided into thirteen equal divisions each of which includes the wheel and one gap. They are spaced such as the height of the wheel has height twice of the gap between the wheels (1:2). The first ring has the radius of 3 units and the thirteenth wheel is of half unit from the axis. The tip of the cone extends to form the formula of compassion which is in bowl shape with height of one unit and the base radius of half unit advancing to one unit. The umbrella covers the formula of compassion and spreads outside. It has height of two units and the radius at the top level adjoined to formula of compassion is two units and it increases as you go down up to three units. Then, lies the Ring which has height of half unit and radius of one and seven eighth unit. Above it lies, the cover of umbrella whose height is one and half unit and radius of one and three fourth unit at the base and increases to two units at top. The moon

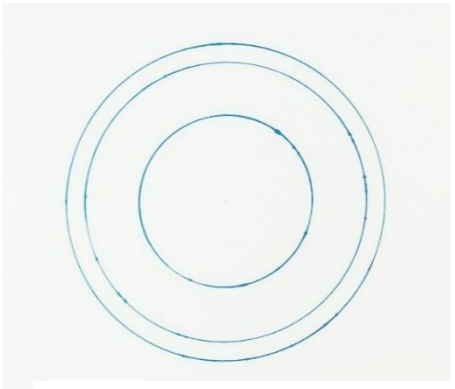
rest on the cover of umbrella and sun above moon. The moon is crescent shape with middle height of one unit and two units as it bends over the edges. The sun lies on top of it with radius of one unit. The moon and the sun are constructed always in the ratio of 1:2. At the top there is spherical pinnacle of radius one unit.

Lotus supporting Umbrella *(Terhatale Muniko Pema)*

The first component is Lotus supporting umbrella. The lotus supporting umbrella has a height of one unit. It is a bowl shaped with its base tip of radius one and half unit and advances to two and half unit from the Centre. The concept of circle and radius is used to make it. With the help of compass, a circular sheet is cut by taking radius one inch greater than two and half unit. Then two circles of 2.5 unit and 1.5 unit is drawn. Then by hammering a 3d object of cone shape is crafted of height one unit. On the lateral surface lotus petal is designed and the carvings are done.



Lotus Supporting Umbrella on



Reference piece for measurement

3 D structure of Lotus Supporting

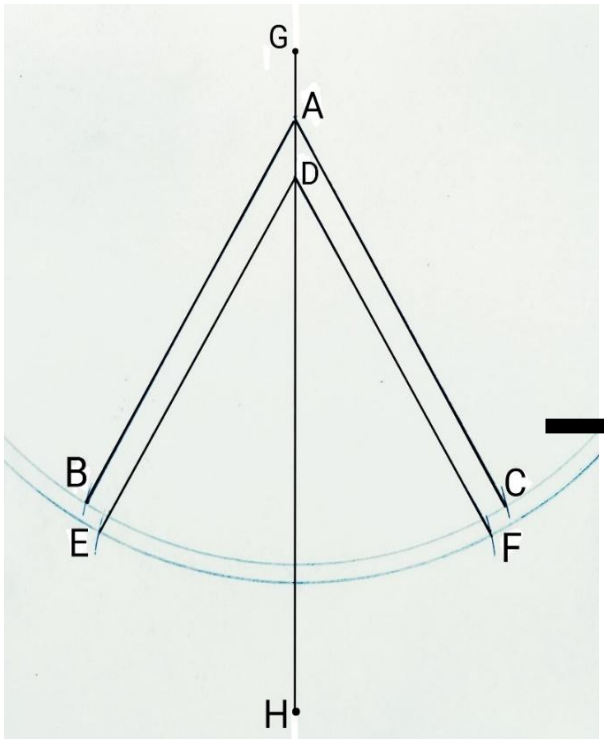
Figure 4.11 Process of making Lotus Supporting Umbrella

Thirteen Wheel *(Terhatale)*

(1) The first (bottom) wheel symbolizes the power of understanding what is appropriate and inappropriate, (2) The second wheel symbolizes the power of understanding that one is responsible for one's own deeds or action, (3) The third wheel symbolizes the power of understanding concentration, liberation meditative stabilization and meditative absorption, (4) The fourth wheel symbolizes the power of understanding the superior and inferior faculties, (5) The fifth wheel symbolizes the power of understanding the various mental inclinations, (6) The sixth wheel symbolizes the power of understanding various mental faculties/constitutions, (7)The seventh wheel symbolizes the power of understanding the paths leading to all goals, (8) The eighth wheel symbolizes the power of understanding the recollection of former existence, (9) The ninth wheel symbolizes the power of understanding deaths and births, (10) The tenth wheel symbolizes the power of understanding the exhaustion/cessation of contaminations, (11) The eleventh wheel Symbolizes the first peculiar close mindfulness (of the Tathagata), that by which, when the Tathägata teaches the dharma to his retinue, he does not get pleased when al his disciples listen with great respect, (12) The twelfth wheel Symbolizes the second peculiar close mindfulness, that by which, when the Tathagata teaches the dharma to his retinue, he does not get angry when all his disciples do not listen with due respect, and (13) The thirteenth wheel Symbolizes the third peculiar close mindfulness, that by which, when the Tathagata teaches the dharma to his retinue, he neither becomes joyful nor angry when part of his disciples listen with respect and part do not listen with respect.

The thirteen wheels has total height of fourteen units in a cone shape tapering to the top. The total cone with wheels is divided into thirteen equal divisions each of which includes the wheel and one gap. They are spaced such as the height of the wheel has height twice of the gap between the wheels (1:2). The first ring has the radius of 3 units and the thirteenth wheel is of half unit from the axis.

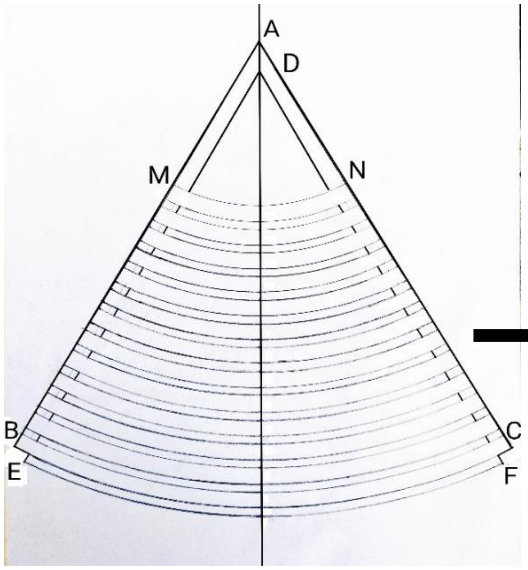
The Thirteen Wheel is cone shaped. Thirteen wheels of descending radius from lower to the upper section is used to create cone shaped structure. Concept of pie is used to make the cone. Compass, scale and measuring tape is used for the measurement.



Sketch of inner section of Thirteen Wheel

Inner section of Thirteen Wheel

3D structure of Thirteen Wheels



Reference piece for measurement

Rings

Figure 4.12 Process of making Thirteen Wheels

Process of Making Reference Thirteen wheels

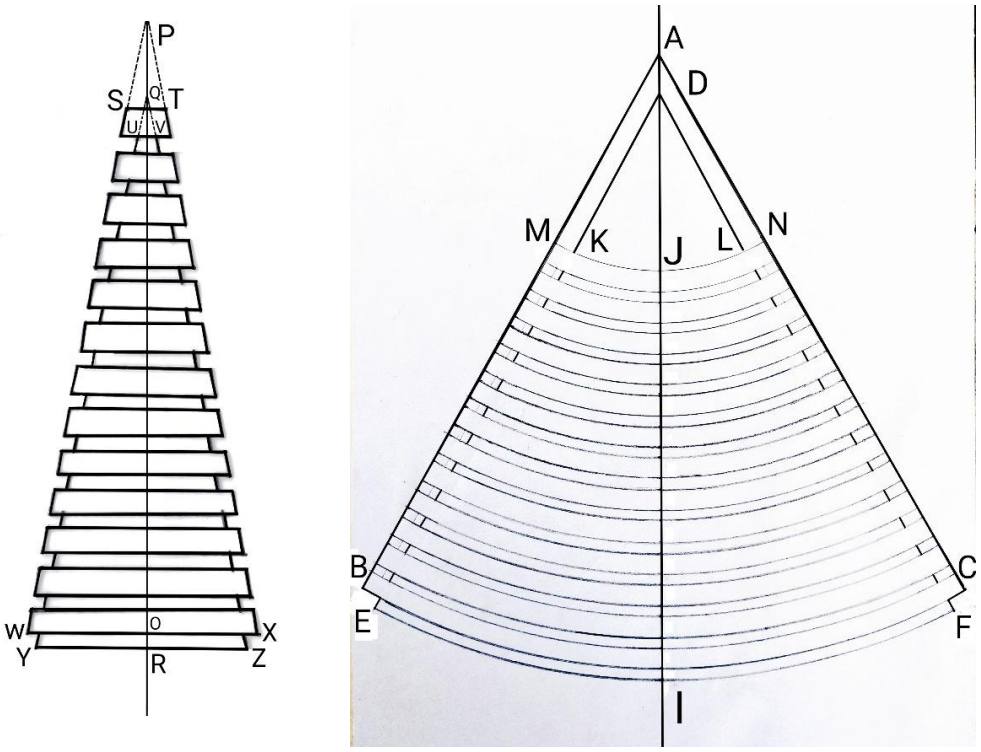


Figure 4.13 Process of Making Reference for Thirteen wheels

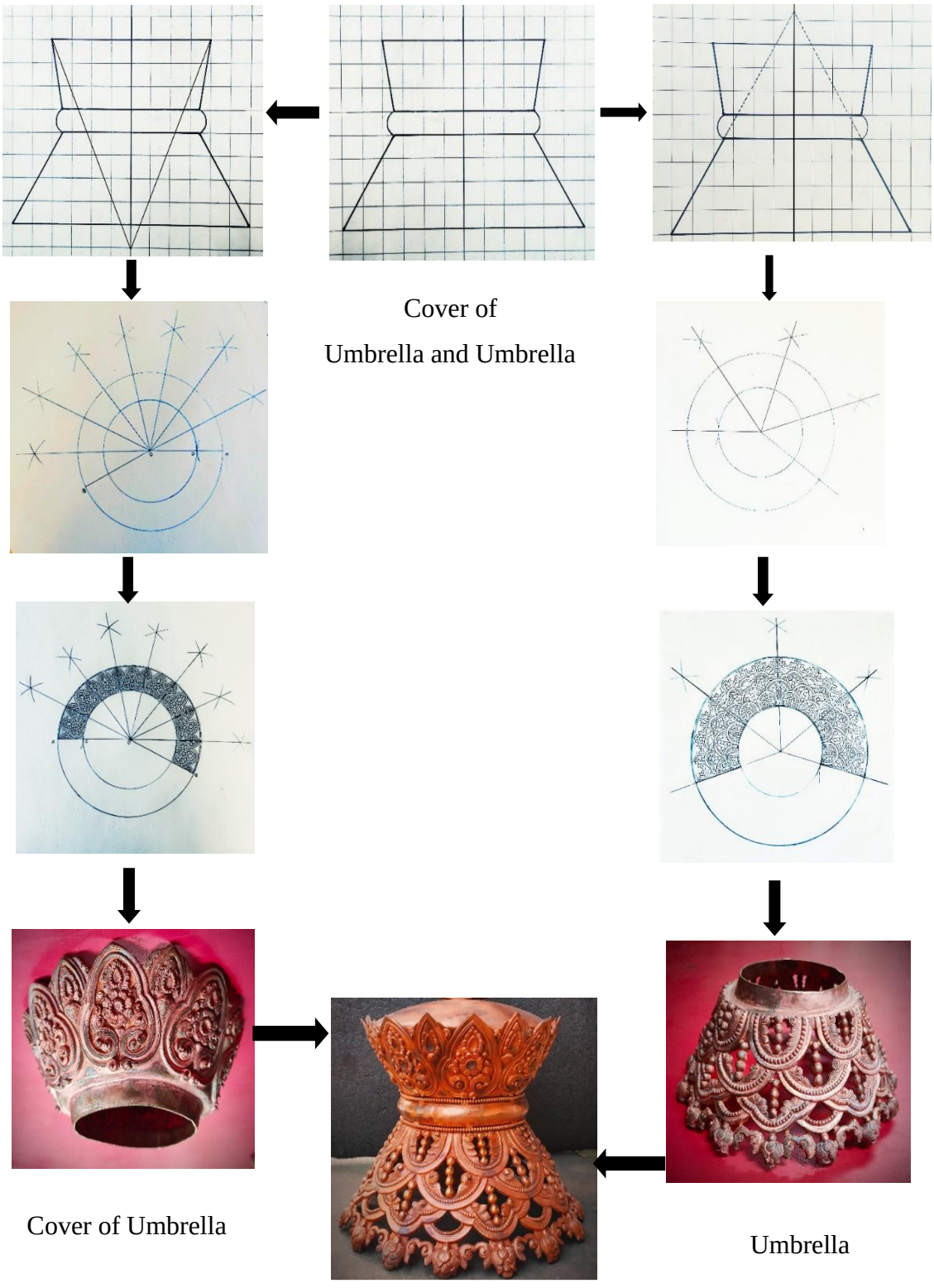
- Slant height XT in plane figure is extended till it reaches the vertical axis and point where it touches is P.
- Slant height ZV in plane figure is extended till it reaches the vertical axis and point where it touches is Q.
- Base line GH is drawn.
- Two arcs from point A and D equal in length of PX and QZ respectively are drawn.
- OX is multiplied by 2 and then by 3.16 then the Arc BC drawn equal to the result value.
- RZ is multiplied by 2 and then by 3.16 then the Arc EF drawn equal to the result value.
- Point A and B, A and C, D and E, D and F are joint.
- Arc MN equal to slant height PT is drawn from Point A.
- Distance from J to I is divided into 26 halves in the ratio of 1:2 (1 being the inner cone and 2 being the outer ring) and the points are marked. Arcs from the point A are drown passing through every points.

- A coppers sheet equal in shape and size of EFLK is cut.
- The sheet is hammered to join EK and FL to make 3D cone structure.
- 13 rings are made from arc MN to arc BC where arc MN is used to make topmost ring and arc BC is used for the lowermost ring.
- These rings are then adjusted around the cone.

Umbrella *(Tala Ko Jhul)* and Cover of Umbrella *(Mathi Ko Jhul)*

The umbrella covers the formula of compassion and spreads outside. It has height of two units and the radius at the top level adjoined to formula of compassion is two units and it increases as you go down up to three units. Then, lies a ring which has height of half unit and radius of one and seven eighth unit. Above it, lies the cover of umbrella whose height is one and half unit and radius of one and three fourth unit at the base and increases to two units at top.

Both the Umbrella and the Cover of Umbrella are cone shaped. Concept of pie is used to make the cone. Compass, scale and measuring tape is used for the measurement. The ring is cut into rectangular shape and then molded in circular shape through hammering.



3D structure of Cover of Umbrella and Umbrella

Figure 4.14 Process of making Umbrella and Cover of Umbrella

Process of Making Reference for Umbrella

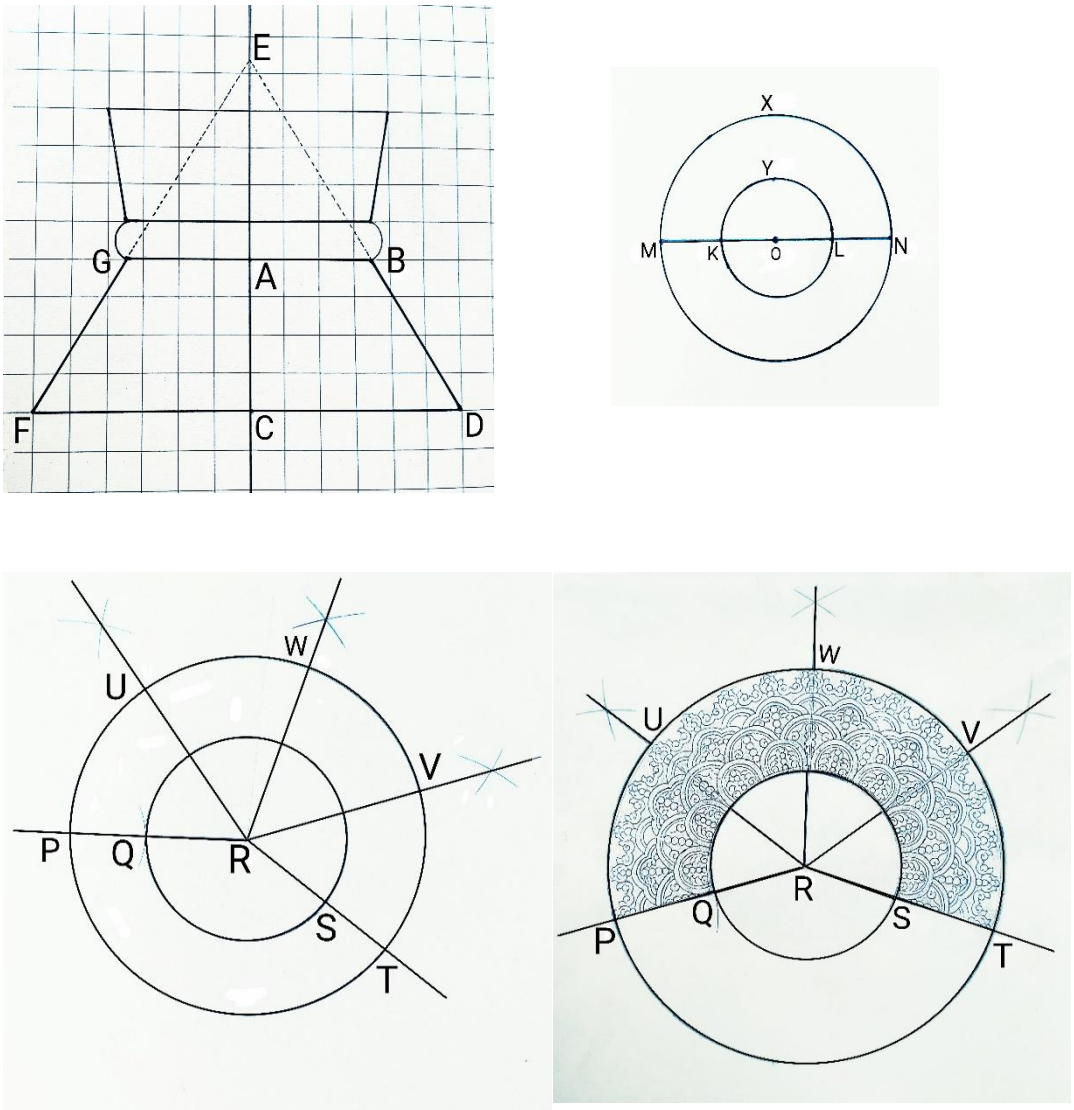


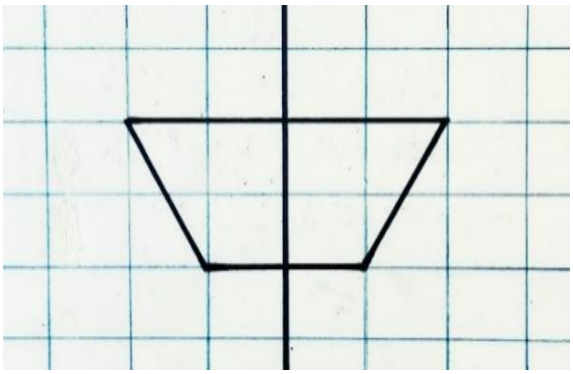
Figure 4.15 Process of Making Reference for Umbrella

- Radius equal to AB and CD are taken to draw two circles.
- BD is extended till it touches a point (E) at the axis and the total length of slant height of DE is taken as a radius to draw next circle ie, DE=PR. Next, BE (DE-BD) is taken as a radius another drawn next small circle inside the previous one.
- An arc PWT equal to the circumference MXN is drawn from P with R as a center.
- An arc QZS equal to the circumference KYL is drawn from Q with R as a center.

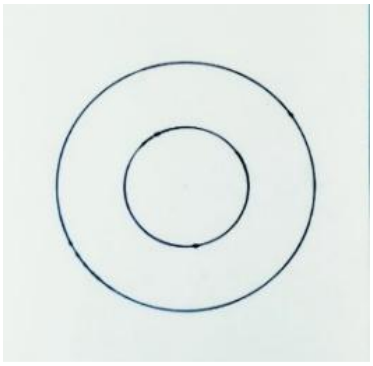
- Next method used by the artisans to find the circumference MXN is the use of pie. Two times of CD is multiplied by pie to find the circumference MXN which is equal to arc PWT. The same process is repeated to find the measurement of arc QZS.
- Portion between the arc PWT and arc QZS is taken to design and make 3D structure of the Umbrella.
- Two faces of the copper sheet (PQ and ST) are joint through welding to make cone shape 3D structure.

Formula of Compassion *(Terhatale Mathiko Pema)*

Atop the thirteenth wheel rests the structure of "Formula of Compassion. It is in the form of the offering cup. The one-third of its upper part has to be encircled by many coil-shaped in bas-relief. The "Umbrella (should equal the seventh wheel: the "Cover of Umbrella the width of the sixth wheel, and the crown structures of the latter two are usually made of ornate perforated metal, although sometimes it is produced in a non-perforated form. The Formula of Compassion and the Umbrella are hidden within the ornate metal crown. The tip of the cone extends to form the formula of compassion which is in a bowl shape with a height of one unit and the base radius of half unit advancing to one unit. The umbrella covers the formula of compassion and spreads outside. At first, the copper sheet is cut into a circle of radius equal to half the upper breadth of the trapezium. Then the lotus petal design is crafted by hammering the sheet to make the petal shape in 3D.



Formula of compassion on Graph



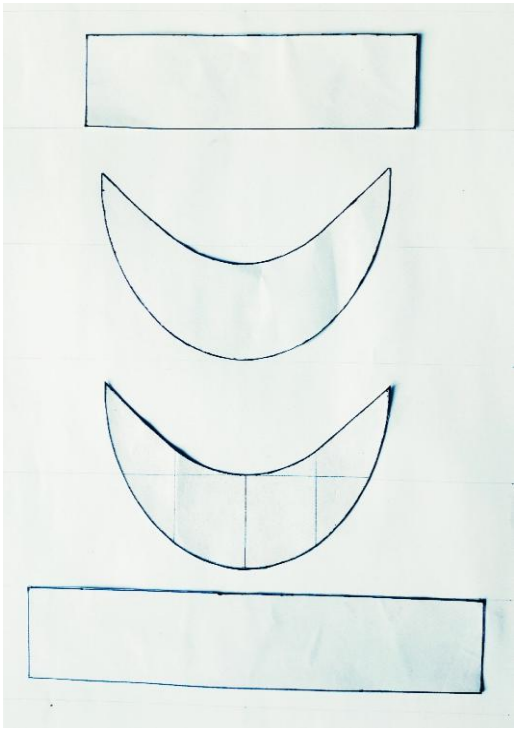
Reference for Making
Formula of Compassion

3D Structure of Formula of Compassion

Figure 4.16 Process of Making Formula of Compassion

Moon *(Joon)*

The moon rest on the Cover of Umbrella below the Sun. The moon is crescent shape with height of one unit and two units as it bends over the edges. Two crescents are joined by two rectangular sheets to create 3D structure of the moon. The length of the smaller sheet is equal to the upper arc of the crescent whereas the length of the bigger sheet is equal to the lower arc of the crescent. Breadth of both the sheets are of one unit.



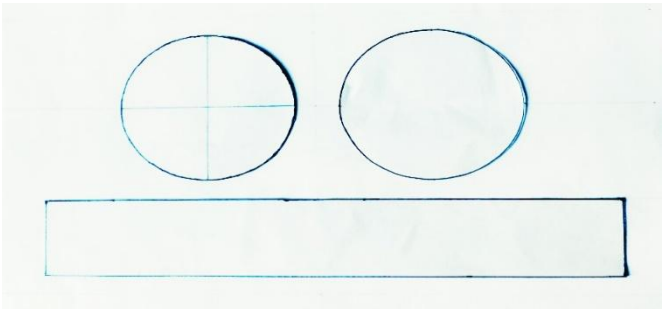
3D structure of the Moon

Reference piece for measurement

Figure 4.17 Process of making Moon

Sun *(Gham)*

The Sun lies on top of the Moon with radius of one unit. The Moon and the Sun are constructed always in the ratio of 1:2. Sun is made with two circular disc and are joint with the rectangular sheet to create 3D shape as of the sun. The radius of the circle is one unit. Breadth of the rectangular sheet is one unit and its length is equal to the circumference of the circular disc.



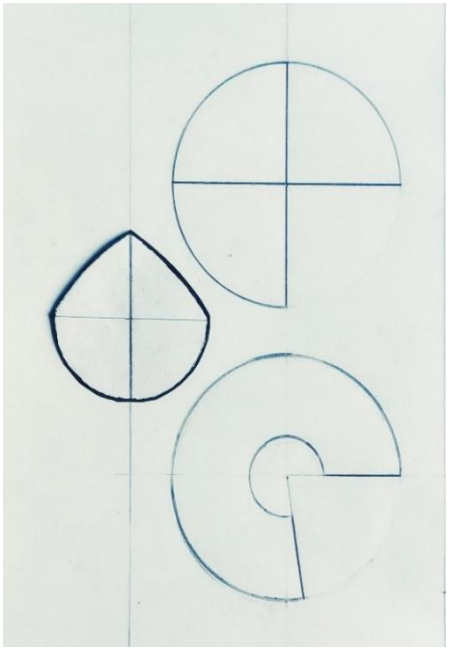
Reference piece for measurement

3D structure of the Sun

Figure 4.18 Process of making Sun

Spherical Pinnacle *(Tara)*

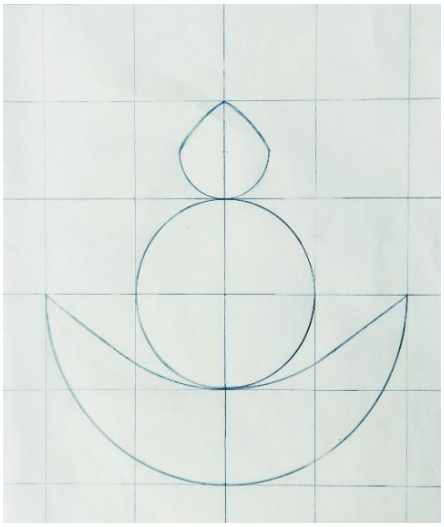
At top, there is spherical pinnacle of radius half unit. Artisans uses a circle of radius half unit to make the upper portion of the Spherical Pinnacle. The circular sheet is cut into four equal sector and three of them is used to make the upper portion. For lower portion, slightly bigger than three sectors are used. These sectors are hammered to create a 3D structure of the Spherical Pinnacle.



Reference piece for measurement

3D structure of the Spherical Pinnacle

Figure 4.19 Process of making Spherical Pinnacle



Sketch of the Moon, the Sun and The Spherical Pinnacle

3D structure of the Moon, the Sun and the Spherical Pinnacle

Figure 4.20 Process of making the Moon, the Sun and the Spherical Pinnacle

Use of Arithmetic in Making Stupa

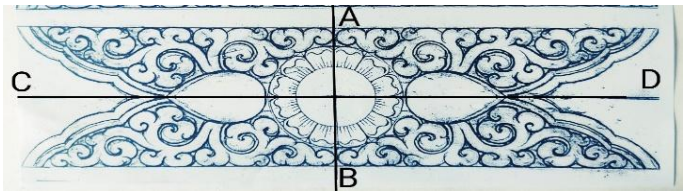
- The use of unitary method can be observed during estimation of the total cost of the copper required for the stupa. For example, the cost of 1kg copper is Rs.1570. To construct a stupa of height 2 m, 130 kg of copper is required. The total cost of the copper is calculated by multiplying *(Guna)* the rate which is Rs.1570 and Quantity of Copper which is 130kg.This gives the total cost of copper Rs. 204,100.
- To make a stupa of large size they photocopy the graph of the stupa by enlarging to the required scale. For example, to make stupa of 6 feet from 5ft measurement the required quantity 6ft is divided by current quantity 5ft and then multiplied by 100 to get the percentage of enlargement. The figures of 5feet stupa is then enlarged by the calculated percentage and further work is proceeded. Hence, the concept of percentage and enlargement was found to be applied.

Pedagogical Implication of Mathematical Practices in Making Stupa

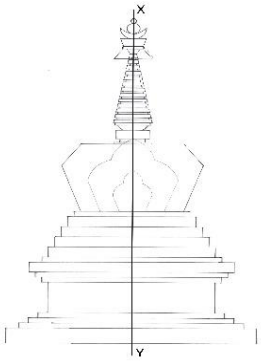
Making Stupa engages complex processes from designing in paper to converting it into 3D structure. However, it involves simpler school mathematics such as symmetry, weight, similarities, congruent, parallel lines, vertex, coordinate, lines, angles, pie, enlargement, reflection etc. Students can easily be taught about the such concept by linking with the making of the Stupa. As Nepal is home to thousands of stupa which can be found on every corners and schools may find it in an accessible place. Such Stupa can be used as a teaching material for the mathematical education. Pedagogical implications of mathematical practices in making Stupa are listed and discussed below.

- Graphs and vertex are used by the artisans to design the framework of the Stupa. Thus, design of the stupa can be linked with the concept of graphs, vertex and coordinates to teach the students practically.
- Given that the practical use of Pie is often questioned by the student and teachers finds it difficult to suggest its uses, the use of its concept in making Thirteen wheel, Vase, Umbrella and Cover of Umbrella of the stupa gives exact answer to such questions.

- Stupa is generally made from copper and engage weighing it as per the size and thickness of the components. For instance, a stupa of 2 Meter height requires 130 Kg of copper. This can be used by the teacher to teach the concept of weight and conversion of units (eg Kg to gram).
- Weighing the copper involves the basic concept of unitary method. Students could be taught practically about the unitary method.
- Vertical axis XY divides the Stupa into two equal halves. To provide the concept of symmetry, plane design of the Stupa can be half split. The figure below shows a sample of carving (*Patta*)used in the plinth which is symmetrical on both axes AB and CD. Due to symmetry, artist design only the quarter portion of the design.



Carving(*Patta*) used in the Plinth



Section of Stupa

Figure 4.21 Example of Symmetry

- Various designs of traditional carvings are carved on the stupa which are same in size and shape. Likewise, same in shape and similar in size are also carved. This might be used by the students to develop the concept of similarity and congruence. The figure (a) shows the design (*Patta*) used in first and second step of four steps which are similar in shape. The figure(b) are congruent designs(*Patta*) used in first step of four step which are similar in both shape and size.

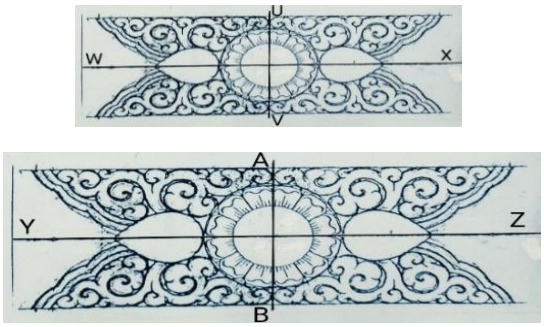


Fig (a) Example of similarity

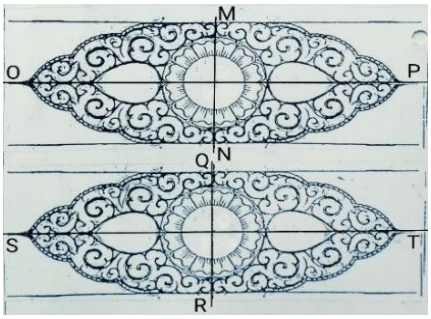


Fig (b) Example of Congruence

Figure 4.22 Example of Similarity and Congruence

- Straight lines are often used in making stupa from the initial step and more than two lines are used which have to be parallel to each other. To give the concept of parallel lines, stupa can be used.
- Artisans converts the 2D figure into 3D concrete structure. This can be used as an example to teach about the plane figure and solid figure.
- At the initial phase of plane figure design, the artisans find the measurement of each lines, points and geometry with the help of their basic knowledge of construction. Through this, difficulties on the topics related to construction at the school level can be eased.
- Lions carved on the main façade of the Stupa face each other in exact opposite direction. Four pairs of lions are carved in the four direction of the stupa. This can be used to teach the concept of reflection

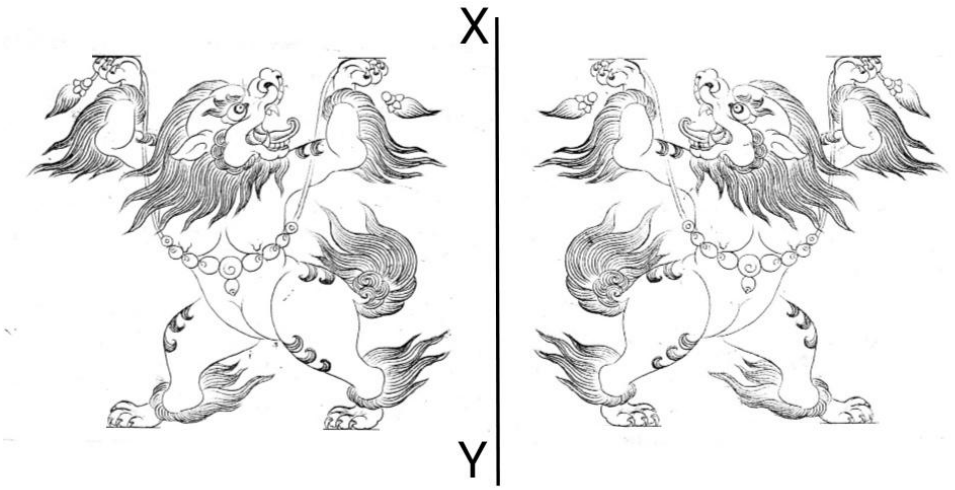


Figure 4.23 Example of Reflection

- Plane figure which includes square, rectangle and solid figure which includes cuboid and cone are used in making the Stupa. This can be used to teach the concept of plane and solid figure.
- The original plane figure is enlarged according the required size which involves the concept of enlargement. This can be used to teach the student about the concept of Enlargement.
- Making of the Stupa requires the use of many geometric shapes which can be used to explain about the geometric figures and basic concept of geometry.

Chapter V

Finding, Conclusion, Implications and Suggestions

The study was conducted to explore the answer to the two research questions namely, 1) What are the use of mathematics in making Stupa and 2) What are the pedagogical implication of mathematical practices in making stupa. For this, the research used the qualitative research approach with observation and interview as a data collection tool. Research sites and the sample for interview were selected purposively.

Findings

Through the analysis and interpretation of data, use of basic mathematics in making stupa has been explored. Mathematics used in the school level are highly used by the artisans. Following findings are drawn from my study,

- Concept of graphs and vertex are used by the artisans to design the framework of the Stupa.
- The concept of Pie is used in making Thirteen wheel, Vase, Umbrella and Cover of Umbrella of the stupa. The lateral surface area of the 3D cone where carvings are done is determined by constructing arcs. The value of arcs are obtained by multiplying the breadth of the objects from graph and pie.
- Raw materials used in making stupa are copper and iron. Buying the raw materials and selling the final product needs the concept of profit and loss.
- Copper and iron are weighted during their purchase which uses the concept of weighing and conversion of units.
- Weighing the copper involves the basic concept of unitary method.
- The concept of vertical axis is used to divide the Stupa into two equal halves.
- Straight lines are often used in making stupa from the initial step which have to be parallel to each other.
- Conversion of 2D figure into 3D concrete structure are carried out by the artisans.

- At the initial phase of plane figure design, the artisans find the measurement of each lines, points and geometry which requires the basic knowledge of construction.
- Square, rectangle, cuboid, cone and many geometric shapes are used in making the Stupa.
- The original plane figure is enlarged according t he required size which involves the concept of enlargement.

Conclusion

Stupa carries a great significance in Buddhist religion are interlinked with the tradition and belief. Artisans have been constructing different types of stupa since the ancient time. The knowledge of making stupa has been passed from generation to generation. The fundamental concept stupa design and construction have not changed till date which has been possible just because of the use of mathematics. Knowingly or unknowingly, artisans use fundamental concepts of mathematics blended with the traditional knowledge. These artisans are trained more than educated. Providing formal mathematical education to them makes the design accurate and construction easier.

As shared by the interviewee, inclusion of mathematic curriculum related to the use of the stupa will help pass the knowledge easily to the next generation. This will help to conserve the traditional knowledge and culture too. Next, stupa is such a structure where use of mathematics from unitary method to coordinates to geometry can be demonstrated practically at one place so, school students have to be brought to visit the nearby stupas and interact with the artisans to learn the practical use mathematics.

Implications

Making Stupa engages complex processes from designing in paper to converting it into 3D structure. However, it involves simpler school mathematics such as symmetry, weight, similarities, congruent, parallel lines, vertex, coordinate, lines, angles, pie, enlargement, reflection etc. Students can easily be taught about the such concept by linking with the making of the Stupa. As Nepal is home to thousands of stupa which can be found on every corners and schools may find it in an accessible

place. Such Stupa can be used as a teaching material for the mathematical education. Pedagogical implications of mathematical practices in making Stupa are listed and discussed below.

- Graphs and vertex are used by the artisans to design the framework of the Stupa. Thus, design of the stupa can be linked with the concept of graphs, vertex and coordinates to teach the students practically.
- Given that the practical use of Pie is often questioned by the student and teachers finds it difficult to suggest its uses, the use of its concept in making Thirteen wheel, Vase, Umbrella and Cover of Umbrella of the stupa gives exact answer to such questions.
- Stupa is generally made from copper and engage weighing it as per the size and thickness of the components. For instance, a stupa of 2 Meter height requires 130 Kg of copper. This can be used by the teacher to teach the concept of weight and conversion of units (Kg to gram, Meter to cm, Feet to Inch).
- Weighing the copper involves the basic concept of unitary method. Students could be taught practically about the unitary method.
- Vertical axis divides the Stupa into two equal halves. To provide the concept of symmetry, plane design of the Stupa can be half split.
- Various designs of traditional carvings are carved on the stupa which are same in size and shape. Likewise, same in shape and similar in size are also carved. This might be used by the students to develop the concept of similarity and congruence.
- Straight lines are often used in making stupa from the initial step and more than two lines are used which have to be parallel to each other. To give the concept of parallel lines, stupa can be used.
- Artisans converts the 2D figure into 3D concrete structure. This can be used as an example to teach about the plane figure and solid figure.
- At the initial phase of plane figure design, the artisans find the measurement of each lines, points and geometry with the help of their basic knowledge of construction. Through this, difficulties on the topics related to construction at the school level can be eased.

- Lions carved on the main façade of the Stupa face each other in exact opposite direction. This can be used to teach the concept of reflection.
- Plane figure which includes square, rectangle and solid figure which includes cuboid and cone are used in making the Stupa. This can be used to teach the concept of plane and solid figure.
- The original plane figure is enlarged according the required size which involves the concept of enlargement. This can be used to teach the student about the concept of Enlargement.
- Making of the Stupa requires the use of many geometric shapes which can be used to explain about the geometric figures and basic concept of geometry.

Suggestions

Based on my study on the use of mathematics in making stupa, the suggestions have been drawn,

- Proving formal mathematical concept to the artisans makes the design accurate and construction easier.
- Use of modern mathematical tools on the entire process of making stupa will simplify the work of artisans.
- Documenting the practice and use of mathematics should be carried out for the future reference.
- Development of formal mathematic curriculum related to stupa should be developed so as to easily pass the knowledge to the next generation artisans and artists.
- Stupa should be taken as a teaching material to teach the basic to higher mathematics.
- School students should be given chance to visit the nearby stupas and interact with the artisans to learn the practical use mathematics.
- School education should be connected to the traditional knowledge of making stupa.

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Appendices

Appendix I

In- depth Interview questionnaire for designer, expert and artisans associated with making stupa.

Personal Details:

Name: Occupation: Age: Education:

The interview took the basis of the following topics,

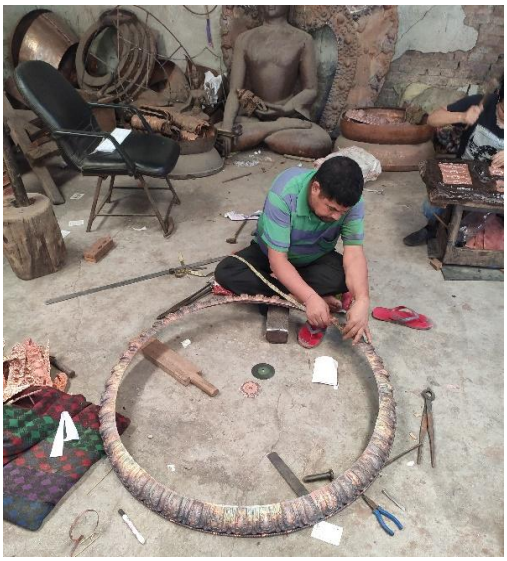
- Development of stupa
- Religious importance
- Linkage with mathematics
- Measure scale to make stupa
- Process of making stupa
- Types of stupa
- Materials used in making stupa
- Design and size
- Importance of mathematics in making stupa
- Numerical concepts
- Basic operation
- Geometrical concept
- Pedagogical implications

Appendix II

Participant Observation Form (guidelines)

S.N	Mathematical concepts	Area of application	Process of application
1.	Basic mathematical operation - Addition and subtraction - Multiplication and division		
2.	Number and Number system - Natural number - Fractional number - Decimal number - Ratio		
3.	Geometrical concepts - Point - Straight lines - Angles - Parallel lines - Perpendicularity - Polygons - Circle - Cone - Congruency - Similarity - Bisector - Symmetry		

PHOTOGRAPHS

Photos during Data Collection

Enlightment Stupa