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Rolle's Theorem and its application in *Tharu's* traditional house

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Abstract
The indigenous people *Tharu's* have a distinctive culture and way of life. While performing daily tasks, they practice their own mathematical concepts and thinking. The study of mathematical ideas and skills that are common within a population but are often not included in the formal curriculum. This study intends to reveal the secret mathematical expertise and knowledge used in *Tharu's* traditional House. The observation and documentation analysis approach was utilized in this study's data collection to attain its objectives. This study is intended to uncover the mathematical concepts embedded in the construction of traditional *Tharu* houses. The resketching of the image of the traditional houses obtained in the field is carried out to facilitate the mathematical ideas in the construction of the traditional house.
This finding demonstrates that Rolle's Theorem is applicable in practice and is clear enough to comprehend its principles from *Tharu's* traditional home.

Keywords: Tharu's, traditional house, indigenous knowledge, Rolle's theorem, application

Introduction
Nepal is a multilingual, culturally, and religiously diverse country. It is diverse geographically, linguistically, caste-wise, ethnically, religiously, and culturally. There are 59 indigenous nations, each with its own culture. *Tharu* is one of them. The *Tharu* are a major ethnic group in Nepal, accounting for 6.2 percent of the total population (Census, 2021) [1]. They inhabit in the Terai area, which runs west from Kanchanpur to east from Jhapa. They generally inhabit in the inner Terai region's twenty-two Tarai districts. The Tharus are divided into subgroups due to their cultural and linguistic variety. Kochila is known in the eastern Terai, Chitwania and Desauria in the middle, Deukhuria and Dangaura in the central Terai, and Rana in the far western Terai. Each subgroup is made up of a mix of ethnic features and everyday practices based on ethnomathematical principles. As a result, this study will investigate what, how, and what significance ethnomathematical notions have in Nepal's *Tharu* population.
The term ethnomathematics refers to ethno and mathema, with ethno referring to sociocultural contexts (e.g., language, jargon, code of behavior, myths, and symbols) and mathema referring to knowing, understanding, explaining, and performing activities to cipher, measure, classify, order, infer, and model. Finally, the suffix tics has the same root as art and technique (D'Ambrosio, 1985) [2]. Ethnomathematics emphasizes awareness of the varied techniques of performing and comprehending mathematics that are influenced by cultural values, traditional concepts and notions, and ethnic environmental situations. (Rosa & Shireley, 2016) [10].
Everyday existence is imbued with a culture's knowledge and traditions. Individuals often compare, classify, quantify, measure, explain, infer, generalize, and evaluate utilizing material and intellectual instruments unique to their culture (D'Ambrosio, 2006) [3]. Human cultural activities invented mathematical knowledge, techniques, and conceptions.
Ethnomathematics is the study of how people use mathematics in their daily lives all across the world. It entails researching how different cultures or tribes solve problems mathematically in order to get the optimum solution for daily operations. Traditional mathematical conceptions may differ from Western mathematical notions because they are heavily influenced by the environment, reasoning, and inference procedures, cultural traditions, mythologies, codes, symbols, and religions. Ethnomathematics encompasses more than just mathematics, ethnicity, and multiculturalism. Ethnomathematics is a field of study that combines philosophy, linguistics, pedagogy, anthropology, and history, and it has pedagogical implications for comprehending different sociocultural settings (Rosa & Shireley, 2016) [10].

Pradhan (2012; 2017) [6-7] discovered that the Chundara people employed the concept of geometry in their work. In their wooden works, they utilize the frustum of cone, cylinder, and notions of height and base perimeter of cylinder, capacity and volume, concept of transformation, and axis of rotation. According to (Millroy, 1992) [9], this act of planning and creating woodwork from generation to generation without any formal means of transfer is called tacit knowledge.

Mathematics is one of the subjects that allows culture and its high ideals to be integrated. The existence of ethnomathematics, in particular, acts as a solution to the problems of cultural preservation, technical advancement, and creative mastery. D'Ambrosio (2006) [3] defines ethnomathematics as a technique for describing the link between culture and mathematics. The research of *Tharu's* ethnomathematics and its linkages to mathematical concepts taught in schools should consequently follow next. Because ethnomathematics is a relatively new concept or program in the educational field, there aren't many publications about Tharu's culture that cover the subject. This is consistent with Powell's claim that anthropometrics is a relatively new field of study with a logical structure (Powell & Frankenstein, 1997) [5].

Tharu's traditional house is one of the remaining cultural artifacts. Ethnomathematics is widely employed in *Tharu's* culture and is still evolving without the *Tharu* people being aware of it. The construction of this traditional dwelling is very distinctive. Mathematical concepts can be included in the architecture of the *Tharu's* dwelling. The components are a systematic arrangement of geometric shapes with mathematical underpinnings and ethnomathematical features. Because each group of people must build their own mathematical system, each culture has its own mathematics. *Tharu's* traditional house employs the concept of numerous types of mathematics, which is the most intriguing concept uncovered as a result of the investigation.

The main objective of this study was to investigate the ethnomathematical concepts that were incorporated into the activities that took place in traditional houses in the *Tharu* community in Nepal, with the goal of addressing the research topics listed below.

- What mathematical principles are present in traditional *Tharu's* houses?
- How does the *Tharu* culture apply Rolle's Theorem to traditional house construction?

Method

The main objectives of our research were to investigate mathematical notions embedded in *Tharu's* traditional house and to assess their applicability in the process of teaching school mathematics. To do this, we chose the qualitative research approach because we wanted to make sense of the complicated world of mathematical ideas and knowledge built-in in the children's out-of-school context. The primary focus of qualitative research is the collection of qualitative data. It is a topic of study that spans disciplines and subjects (Denzin & Lincoln, 2005) [4]. We used a qualitative study design for our work in order to make sense of the complicated world of traditional houses, the mathematical knowledge hidden in traditional houses, and its consequences in school mathematics instruction. Such ideas, perceptions, and knowledge would be impossible to quantify with numbers and statistics. People's sentiments, beliefs, perceptions, attitudes, and understanding of their activities, as well as the mathematical conceptions embedded in cultural objects, cannot be quantified.

To learn about the practical application of Rolle's theorem, we chose 4 students from Gyanjyoti School in Tulsipur Dang Nepal who are in class 12. They observe and analyze the *Tharu's* traditional houses before selecting one and measuring it according to their data.

Result and Discussion

Tharu's ethnomathematics is a collection of fundamentally sound objects that reveal a fundamental knowledge of mathematical notions. *Tharus* lived in Tharu's dwellings, which he redesigned using his mathematical knowledge, know-how, and skills. Several studies have been performed to investigate additional links between ethnomathematics and well-established cultural practices (Pradhan, 2017; Pramudita & Rosnawati, 2019; Owusu-Darko, Sabtiwu, Doe, Owusu-Mintah, & Ofosu, 2023) [7, 8, 11].

The elderly man builds traditional *Tharu*'s houses. Stones, clay, wood, and Khar are used to construct the house. The roofs are tilted because Khar is thatched. A house's principal functions are to provide a place to live and a place to store belongings; dwellings are built to meet human requirements. Window, door, and ventilation management. There are fixed tiny apertures for air flow. People have a tradition of painting vivid artwork on their walls. Decorations are made from stone and wood carvings. In this research we establish real life application of Rolle's Theorem from *Tharu's* traditional house.

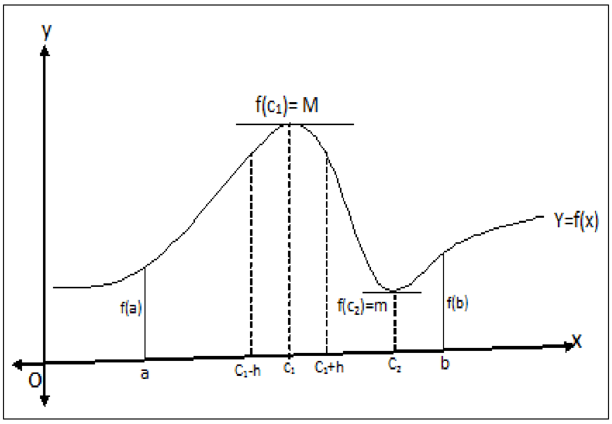
Rolle's Theorem

If a function $f(x)$ is

1. Continuous in the closed interval $[a, b]$
2. Derivable in the open interval (a, b) and
3. $f(a)= f(b)$

Then there exists at least one value $c \in (a, b)$ such that $f'(c) = 0$.

Proof



The function $f(x)$ being continuous in the closed interval $[a, b]$, it is bounded and attains its bounds in the interval [a, b]. Let the least upper bound (l. u. b.) and greatest lower bound (g. l. b.) of the function $f(x)$ in the intervals [a, b] be M and m. There exists two numbers c_1 and c_2 in the closed interval [a, b] such that $f(c_1) = M$ and $f(c_2) = m$.

Now two cases arise:

Case I

When $M = m$.

Then $f(x) = M = m$ at each point in $[a, b]$

i.e. $f(x)$ is constant for every $x \in [a, b]$

$f'(x) = 0, \forall x \in [a, b]$

Hence the theorem is true for any value c of x in the open interval (a, b).

Case II

When $M \neq m$.
In this case either M or m will be different from $f(a)$ which is also equal to $f(b)$. Let us suppose that $M = f(c_1)$ is different from $f(a)$ and $f(b)$.
The number c_1 is different from a and b and so lies within the open interval (a, b).
Now, f (c_1) being the greatest value of f, we have

$f(c_1 + h) - f(c_1) \leq 0,$ for all $h > 0$ or < 0.

$$\therefore \frac{f(c_1 + h) - f(c_1)}{h} \leq 0 \quad \text{if } h > 0$$

and $$\therefore \frac{f(c_1 + h) - f(c_1)}{h} \geq 0 \quad \text{if } h < 0$$

Hence

$$\lim_{h \to 0+0} \frac{f(c_1 + h) - f(c_1)}{h} \leq 0$$

and

$$\lim_{h \to 0-0} \frac{f(c_1 + h) - f(c_1)}{h} \geq 0$$, provided the limits exist.

But f is derivable on (a, b), $f'(x)$ exists for every value of x in $a < x < b$, and hence $f'(c_1)$ also exists. For this above two limits must exist and be equal, and the only equal value they can have is zero.

$\therefore f'(c_1) = 0$.

Similarly, the conclusion of $f'(c_2) = 0$ can be obtained when the least value m differs $f(a)$ and
$f(b)$.

Geometrical Interpretation

Let the graph of the function be drawn between $x = a$ and $x = b$. Obviously, it will be a continuous curve between x= a and x= b having a unique tangent at all points in the above interval and $f(a) = f(b)$.
According to Rolle's Theorem, there exists at least one point $x = c$ on the curve between $x = a$ and $x = b$ at which the tangent to the curve is parallel to the axis of x.
We investigated *Tharu's* community traditional house in Nepal to discover the applications of Rolle's Theorem in a *Tharu's* community traditional house in Nepal. We discover that the roof of the home is parabolic in nature, therefore we measure the relevant sections of the house to construct an equation for the roof's cure and apply Rolle's Theorem to that equation.

Fig 1: *Tharu's* traditional house. (Source: field survey)

Fig 2: Measuring different parts of the house. (Source: field survey)

From the first house, we considered the base of one of the faces of the house as X-axis and the edge of vertical wall as Y-axis measured the horizontal length and found it to be 23 units. We also measured the vertical heights at both edges of a face and found them to be 8 units on each side Thus we obtained two coordinates of the parabolic curve of the roof as A (0,8) & B (23,8). We furthered measured the midpoint of that face and the vertical height at that point and found it to be 12 units. Thus, we obtained another coordinate as C (23/2, 12).
Using these three coordinates we found the equation of the curve of the roof as

$$f(x) = -\frac{16}{529}x^2 + \frac{16}{23}x + 8.$$

So, one of the examples relating to Rolle's Theorem originated from *Tharu's* traditional house. And the example is Verify Rolle's theorem for

$f(x) = -\frac{16}{529}x^2 + \frac{16}{23}x + 8$ in [0, 23].

Solution

Here, $f(x) = -\frac{16}{529}x^2 + \frac{16}{23}x + 8$ in [0, 23].

i] Since $f(x)$ is a polynomial. So, it is Continuous in [0, 23].

ii] $f'(x) = -\frac{32}{529}x + \frac{16}{23}$ which is exist in (0,23). So, it is differential in (0, 23).

iii] f (0) = 8

$$f(23) = -\frac{16}{529}\times 23^2 + \frac{16}{23}\times 23 + 8 = 8$$

So, f (0) = f (23)

All the conditions of Rolle's Theorem are satisfied then there exists at least one value of

$c \in (0,23)$ such that $f'(c) = 0$

or, $-\frac{32}{529}c + \frac{16}{23} = 0$

$$\therefore c = \frac{23}{2} \in (0,23)$$

Hence, the Rolle's Theorem is verified.
This means that the tangent drawn at C (23/2, 12) is parallel to the X-axis which we have considered to the base of the house.
Thus, the theoretical value matched with the value that we have got by measuring.
Similarly, from the second house, we considered the base of one of the faces of the house as the X-axis and the edge of the vertical wall as the Y-axis measured the horizontal length, and found it to be 23 units. We also measured the vertical heights at both edges of a face and found them to be 8 units on each side Thus we obtained two coordinates of the parabolic curve of the roof as A (0,4) & B (10,4). We further measured the midpoint of that face and the vertical height at that point and found it to be 6 units. Thus, we obtained another coordinate as C (5, 6).
Using these three coordinates we found the equation of the curve of the roof as

$$f(x) = -\frac{2}{25}x^2 + \frac{4}{5}x + 4.$$

So, other examples relating to Rolle's Theorem originated from *Tharu's* traditional house. And the example is Verify Rolle's theorem for $f(x) = -\frac{2}{25}x^2 + \frac{4}{5}x + 4$ in [0, 6].

Solution
Here, $f(x) = -\frac{2}{25}x^2 + \frac{4}{5}x + 4$ in [0, 6].

i] Since *f*(*x*) is a polynomial. So, it is Continuous in [0, 6].
ii] $f'(x) = -\frac{4}{25}x + \frac{4}{5}$ which is exist in (0,6). So, it is differential in (0,6).
iii] f (0) = 4

$f(6) = -\frac{2}{25}\times 6^2 + \frac{4}{5}\times 6 + 4$ So, f (0) = f (6)

All the conditions of Rolle's Theorem are satisfied then there exists at least one value of
$c \in (0,6)$ such that $f'(c) = 0$

or, $-\frac{4}{25}c + \frac{4}{5} = 0$
$\therefore c = 5 \in (0,6)$

Hence, the Rolle's theorem is verified.
This means that the tangent drawn at C (5, 6) is parallel to the X-axis which we have considered to the base of the house.
Thus, the theoretical value matched with the value that we have got by measuring.
In this way, we can use Rolle's Theorem in *Tharu's* traditional house.

Conclusion
Many mathematical concepts have cultural contexts. Calculus appears to be present in *Tharu's* ethnomathematics. As evidenced through dialogues and assessments of *Tharu's* residences, the formal and informal mathematical concepts integrated in the school-based curriculum are more clearly interconnected. The pedagogical methods obtained from this primary application of ethnomathematics can be employed in a variety of innovative teaching contexts. Because *Tharu* households employ ethnomathematics, children from the villages may follow the lesson plans and improve their mathematical skills. The findings suggested that the *Tharu's* traditional dwellings demonstrate real-world application of Rolle's Theorem.
Tharu's house is known for its informal application of mathematics. The informal posture of knowledge transfer of these ethnomathematical ideas significantly limits the identification of the connection to the formal approach to teaching mathematics. To begin, it is vital to consider formalizing informal ethnomathematics through appropriate ethnomathematical pedagogies in order to respond to the formal curriculum implementation processes in some way. Culture has much to offer math educators if we are willing to accept its absorption into the teaching and learning processes. If we connect Rolle's Theorem with real-world applications, students will find it easier to understand Calculus.
We encourage more research on the practical value of the ethnomathematics approach in educating students about other mathematical ideas in a variety of cultural settings. It is recommended that math teachers use the ethnomathematics technique and incorporate it into the curriculum implementation process to see how it influences math instruction.

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