Physics Phenomena on Housing Architecture in Kampung Naga

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Abstract. Some local wisdom that is preserved by certain tribal communities in Indonesia is considered a myth; however, some other wisdom is also scientific. The purpose of this study is to describe some of the physical phenomena contained in the local wisdom of building in one of the tribal communities in West Java, Indonesia namely Kampung Naga. This research uses descriptive qualitative method. Through the field study, community interviews, literature studies and forum group discussion (FGD), the results of the research are: (1) there are two types of local wisdom of architectural housing in Kampung Naga: scientific local wisdom and non-scientific local wisdom (2) There are physical concepts which are contained in the local wisdom of houses in Kampung Naga: heat transfer, balance point temperature, sun and wind direction and specific heat of materials. This research concludes there are some phenomena of physics in local wisdom of housing architecture in Kampung Naga that is scientific and can be integrated in physics learning in school. This study recommends the importance of an appropriate integration model in physics learning.

1. Introduction

Sundanese, as one of the biggest tribes in Indonesia, has been contributing to the valuable cultural heritage in character building of Indonesia [1]. One of the valuable cultural heritages is an area called Kampung Naga along with its belief, tradition, arts, custom, social norms, and even buildings [2, 3, 4]. Buildings in Kampung Naga, in addition to their unique shapes, should follow the ancestors' advice and instructions [5]. To this relation, some people call this phenomenon a myth while some others consider this as meaningful local wisdom.

Local wisdom is defined as noble values followed and maintained by a certain community or group of society that aim to protect and preserve the local culture and environment. It is believed that preserving local wisdom in teaching and learning materials is such a necessity [6]. Explaining scientific concepts of local wisdom, particularly that exists around the students, can help them relate what they learn to what they experience in their life [7]. Through local wisdom students can also learning cultural values that are influential to their attitude, behaviors, and critical thinking [8].

Physics plays an important role in promoting learning output and learning outcome; by learning physics, students are most likely to be obedient to God, the creator of the universe, love human beings and their environment, and in turn will help form civilized society [9]. However, to reach those goals, there needs to be high quality physics learning [10]. High quality learning is a learning process that is close to the students, facilitating integrated scientific concepts and real experiences of the students so they can relate what they learn to what they experience [11]. The purpose of this study is to investigate several physics phenomena in local wisdom of building architecture in Kampung Naga.

2. Methods

This study employs a qualitative descriptive method. In this study, the first step taking place is a field study. The field study is aimed to gain accurate and factual data on teh local wisdom of building architecture in Kampung Naga and phenomena existing within. The next step following the field study is literature study. This step is carried out to confirm the findings with physics explanations. The final

step in this study is an FGD among researchers to analyze the data found and map physics phenomena that can possibly be implemented in schools.

Subject and site of the study is the people of Kampung Naga. Administratively, Kampung Naga is located in Neglasari, Salawu, Tasikmalaya, Indonesia. It is a village whose people, which belong to Sundanese tribe, strongly hold their ancestors' belief and custom [12].

3. Results and discussion

3.1 Types of Local Wisdom of Building Architecture in Kampung Naga

Table 1 shows the types of local wisdom contained in architecture of houses in Kampung Naga. Data are acquired through field study, observation, and interview with the head of the village. To make the mapping easier and to be in accordance with the purposes of the study, two categories of local wisdom are determined: scientific local wisdom and non-scientific local wisdom.

Table 1. Types of Local Wisdom in the architecture of houses in Kampung Naga

Scientific Local Wisdom	*Non-scientific Local Wisdom*
▪ Buildings in Kampung Naga are mostly triangle with boulders as the foundation that are embedded to the ground and fibers as the roof. ▪ Each house in Kampung Naga faces north and south so that all the houses are face to face and back to back with each other. ▪ Houses have wooden pillars and bamboo walls with *Sasag* webbing. ▪ There is always an under-the-house part in Kampung Naga.	▪ House building in Kampung Naga is always based on the people's ancestors' instruction. ▪ Using modern tools of construction is believed to be a bad luck. ▪ Men are strongly forbidden to have a conversation in the kitchen, especially in *Goah* and *Pandaringan* areas. Those areas are restricted for women only since they believe Dewi Sri is always there. ▪ The location of *Goah* is based on the wife's birthdate. ▪ There is a sacred place called *Bumi Ageung* that is taken care of by menopause women.

The categories of local wisdom shown in Table 1 are based on subjective perspectives of the researchers. Scientific local wisdom refers to activities, occurrences, and phenomena maintained by the people that can be explained scientifically, while non-scientific local wisdom is those maintained by the people with no scientific explanations at all.

3.2 Housing Architecture in Kampung Naga

Housing architecture in Kampung Naga is not too different from those in other *Kampung Adat*, special villages, in West Java. All the houses in Kampung Naga are on stilts which are vertically divided into three main areas namely *Kolong*, and under the house area, main room, and *Para*, the ceiling part which has roof made of fibers. The visualization of a house in Kampung Naga is shown in Figure 1 [13]. In the meantime, the explanation of each part of the house along with the physics concepts and Sundanese cosmological points of view is shown in Table 2.

Table 2. Parts of the Houses in Kampung Naga

Parts of the House (Vertically)	*Function*	*Sundanese Cosmology*	*Physics Concepts*
Kolong (under the house)	Storage for firewood, farming tools, and poultry cages	The underworld	Heat type
Palupuh/ floor (the middle part)	A place for daily activities	The middle world	Balance spots of temperature, wind direction, and the sun
Lalangit/ Ceiling (the upper part) and the roof	Protection from the sun and the rain	The upper-world	Heat transfer

In terms of architecture, houses in Kampung Naga belong to vernacular type of architecture. Vernacular architecture is simply defined as an architectural design that adjusts to the local climate, uses local techniques and materials, and is influenced by social, cultural, and economical aspects of the local people [14]. For Sundanese people, including the people of Kampung Naga, houses are protection from the nature such as rain, wind, sunshine, and wild animals rather than protection from the enemies [15]. Thus, buildings in Kampung Naga are dominated by natural materials such as fibers, dry coconuts, bamboos, wood, and rocks [16]. The visualization of houses in Kampung naga are presented in Figure 2 [17].

Figure 1. Type of house in Kampung Naga

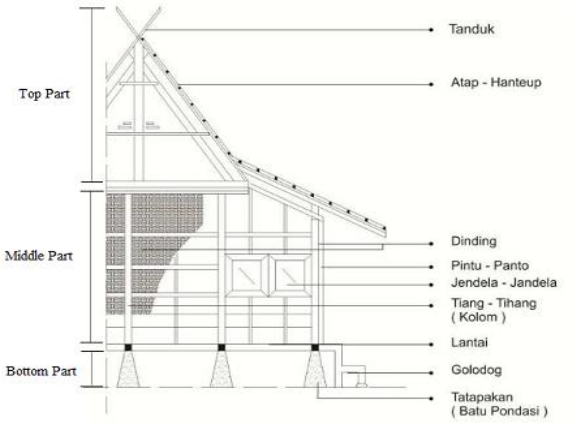

Figure 2. Parts of a house in Kampung Naga

3.3. Physics Phenomena of Local Wisdom on Buildings in Kampung Naga

3.3.1. Fibers Roof and Heat, Heat Absorption, and Heat Transfer

The use of fibers roof is actually an implementation of green roof which gives huge benefits towards the energy efficiency of the buildings. The physics concepts that can be applied in the use of fibers as a roof are those of temperature, heat absorption, and heat transfer. Roof actually functions as a protector of direct sunlight radiation. Radiation received by the roof is formulated as follows.

$$P_{abs} = \sigma \varepsilon A T_{env}^4 \quad (1)$$

In which P_{rad} = heat flow rate, = 5.6703 x 10^{-8} $W/m^2 \cdot K^4$ is called Stefan-Boltzmann, ε constants = emissivity of the roof surface (ranging from 0 to 1). T_{env}= temperature (Kelvin). In addition to the phenomenon of heat transfer in terms of radiation, there is also transfer in terms of convection [18]. Theoretically, this type of transfer occurs when there is fluid that contacts with substance surface on different temperature. There are two types of convectional heat transfer namely natural or free convention and forced convection. Heat transfer between walls or roofs in a house in a quiet day is an example of free convection [19]. The formula of convectional heat transfer is in a form of Newton's law of cooling.

$$q_c = \overline{h}_c A\left(T_s - T_{f,\infty}\right) \quad (2)$$

Where $\overline{h}_c$ = unit thermal convective conductance, or average convection heat-transfer coefficient, at fluid-to-solid interface ($W/m^2.K$), A=surface area in contact with fluid (m^2), T_s= surface temperature (K) and $T_{f,\infty}$= temperature of undisturbed fluid far away from heat-transfer surface (K)

3.3.2. Bamboo Walls and the Concepts of the Building Balance Point Temperature

The middle part of the house is where most of the activities are done in Kampung Naga. In this room, they sleep, receive guests, etc. In architecture, this part should paid attention a lot in terms of comfort, especially related to temperature and air circulation. Physics concept that is related to this is building balance point temperature. The building balance point temperature is a VITAL SIGN indicator of the relationship between the various thermal forces at play within a building; the heat generated by building occupancy, the heat of the sun entering the building, and the transfer of energy across the building enclosure due to the difference in temperature between building and environment [20]. The temperature is presented in Figure 3.

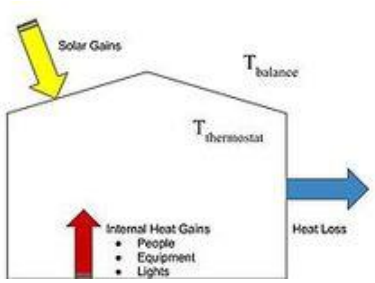

Figure 3. Basic diagram of internal and external gains/losses in a building with balance point temperature (source: https://en.wikipedia.org)

The balance point temperature is mathematically defined as:

$$T_{balance} = T_{thermostat} - \frac{Q_{IHG} + Q_{SOL}}{U_{bldg}} \quad (3)$$

Where $T_{balance}$ is the balance point outdoor air temperature, given in °C (°F), $T_{Thermostat}$ is the building thermostat set-point temperature, given in °C (°F), Q_{IHG} is the internal heat generation rate per unit floor area due to occupancy, electric lighting and mechanical equipment, given in W/m^2 ($Btu/s/ft^2$). This internal heat generation is not constant due to variability in occupancy, lighting, and equipment operation schedule but is largely considered constant to a first order approximation, Q_{SOL} is the

building heat gain per unit floor area due to solar radiation, given in W/m^2 (Btu/s/ft^2). This heat gain is not constant due to solar variability with time of day and year but is largely considered constant to a first order approximation. In winter, it is reasonable to assume Q_{SOL}=0. U_{bldg} is the rate of heat transfer across the building envelope per degree temperature difference between outdoor and indoor temperature and per unit floor area, given in W/°C/m^2 (Btu/s/°F/ft^2). This heat transfer can vary due to variations of fresh air ventilation rate but is largely considered constant to a first order approximation.

3.3.3. North-South Directions

The north-south directions of houses in Kampung Naga can actually be explained scientifically. Theoretically, orientation of buildings is determined to adjust to the climate of the area. The main purpose of this is to comfort the residents even in an unwanted weather.

One of the tropical architecture theories related to this study [21]. This theory states that climate and humidity are significantly influential to the architecture in Indonesia. In the meantime, the characteristics of humid tropical climate is; temperature at 20 ° C, humidity above 60%, and high rainfall intensity in dry season and low rainfall intensity in rainy season [22]. In addition to the climate, humidity, and rainfall, another important factor determinant to the building orientation is the wind direction. Wind direction is generally implemented to maximize the air capacity streaming through the ventilation of the buildings. The basic physical form and orientation of buildings are relative to the wind direction. In a tropical area, sunlight is more "rich" so that heat energy is in bigger amount than the non-tropical area. Therefore, it is assumed that the ideal position of the width of the buildings is in the north and south [23]. Figure 4 shows the scheme of wind direction and the sunlight.

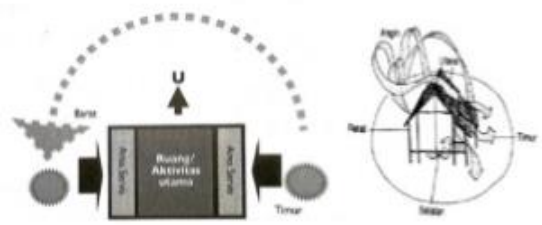

Figure 4. Building orientation based on the direction of the sun movement and the wind

The walls of the building are made of local materials (wood and bamboo) and the design of the house is on stilts. The materials of the design are actually in accordance with the climate of Kampung Naga so that the air within the house is clean. The heat of the air will come out of the walls and the roof. The air will then be exchanged with the fresh air coming in through the walls and the bamboo floor (*Palupuh*).

3.3.4. Each house has a vault heat type of substance

The houses on stilts are actually coming with some benefits for the house owners. The position of the floor that is a lot higher than the ground is influenced by the air around it. Soil, which is the ground of the house, is known to easily receive and release heat. When the floor directly touches the soil, its temperature is very much affected by the soil's temperature. Meanwhile, when the floor is above the soil, the floor's temperature is relatively stable. The physics concept that is in line with this phenomenon is heat type of substance.

This type of heat is simply defined as the heat quantity (joule) that is necessary to increase the temperature of 1 ^{o}C from 1 kilogram of the substance. Its mathematical formula is in the following equation [24].

$$c = \frac{1}{m}\frac{\mathrm{dQ}}{\mathrm{dT}} \quad (4)$$

In the context of Kampung Naga, if the heat of the wood is (J/kg.^{o}C) while the heat of the dry clay is 922 J/kg ^{o}C [25], then to increase the clay's temperature of 1 ^{o}C, 1760 J of the heat is needed, while to increase the wood's temperature, 922 J of the heat is needed.

3.4. *The Necessity of Local Wisdom Integration in Physics Learning in Schools*

Welsh dan Wright (2010) state that cultural literacy helps somebody to make good interaction with their surroundings, either their own culture or others' culture, and to have broaders perspectives towards the world [26]. One of the cultural literacies is local wisdom literacy. Local wisdom literacy can actually be taught through integrated learning in schools. Through simultaneous and continuous education, humans are led to know their Creator, to be wise both to fellow humans and to their environment [27].

However, integrating the local wisdom in terms of context and contents in learning science, particularly physics, has its own challenges. One of the attempts to do so is through authentic and scientific practical transformation in the context of learning [28]. European people have actually been implementing this through Cultural Historical Activity Theory (CHAT). Scientists in the United States, Canada, and Australia have even been developing its theories and research methods [29]. One of the biggest advantages of integrated learning of science and local wisdom is that people will be able to interact well among each other so that they will be able to create a community that preserves their environment [30]. This integration is expected to bring science learning that is down to earth, meaningful, contextual, and easily understood.

4. Conclusion

Based on the data analysis and the discussion of the study, it can be conlcuded that there are several physics concepts existing in the local wisdom of the housing architecture in Kampung Naga. Those concepts include heat transfer, temperature balance point, wind and sun direction, and the heat of substance. In the meantime, the results of the study show that the physics phenomena of housing architecture in Kampung Naga can be integrated in physics learning in schools with some adjustments, either in terms of contents or methods.

Acknowledgments

Research Center of UIN Sunan Gunung Djati bandung is gratefully acknowledged for supporting the research conducted in Kampung Naga, Tasikmalaya, Indonesia.

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