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Enhancing Bamboo Utilization Through Experiential Learning and Architectural Applications

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Abstract
Bamboo, despite its potential as a sustainable building material, remains underutilized due to limited community perceptions and preferences, shaped by insufficient exposure and understanding. This research addresses the challenge by investigating how individual experiences and learning processes influence community attitudes toward bamboo, aiming to develop strategies to enhance its utilization. A mixed-method approach was employed, collecting data from 259 respondents through open- and closed-ended questionnaires, which were analyzed using regression techniques. The findings reveal that experiential learning plays a crucial role in shaping perceptions. Empirical experiences, such as daily interactions with bamboo-based furniture, significantly increase interest in using bamboo for architectural applications ($p < 0.0001$). Likewise, passive learning, including reading articles, viewing photographs, or visiting bamboo structures, enhances awareness of its potential as a construction material ($p = 0.0002$). Additionally, exposure to bamboo in artistic contexts elevates its perceived aesthetic value ($p = 0.0004$). Given the urgent need to promote sustainable materials, this study emphasizes the transformative impact of experiential learning in shifting community perceptions. By integrating bamboo into daily life—through architectural furniture, artwork, and media exposure—and fostering passive learning initiatives such as exhibitions, educational programs, and awareness campaigns, bamboo's acceptance and application in the built environment can be significantly expanded. These findings provide a strategic foundation for promoting bamboo as both a functional and aesthetic material, contributing to sustainable construction practices and ecological conservation efforts.

Keywords: *bamboo; empirical experience; learning process; perception; preference; utilization*

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1. INTRODUCTION

Bamboo material is recognized as an effective alternative to reduce negative environmental impacts due to its ability to sequester carbon and grow quickly (Chainey et al., 2022; Boity et al., 2022). Bamboo has long been used in construction and is part of local cultures (Mcneely, 1999; Silalahi, 2015; Widyowijatnoko & Harries, 2020). As a natural material, bamboo offers advantageous characteristics (Sharma et al., 2015) and can reduce the impact of conventional building materials. Bamboo also has good physical properties for construction (Xinping et al., 2018), such as an excellent strength-to-weight ratio (Devi & Singh, 2021; Marchi et al., 2023;

Xiao, 2008; Yuen et al., 2017). It can be used in various construction elements, with better earthquake and climate change resistance than conventional materials. These advantages make bamboo a more durable and environmentally friendly material (Artiningsih, 2012). However, despite its many advantages, bamboo utilization remains limited due to public perceptions of bamboo as a traditional material that is not strong enough for modern construction (Bredenoord, 2024; Yor Maikol et al., 2020). A lack of understanding and standardization in its use slows down its adoption. Therefore, it is important to change these perceptions through further education and recognition of the benefits of bamboo in the construction sector.

Public perceptions of the use of bamboo as a construction material are influenced by various factors, including aesthetics, strength and durability, and construction techniques and development. Bamboo is seen as having strong visual appeal, as well as good characteristics for durable and safe construction (Vijayalaxmi & Singha, 2021; Dewi, P., 2020; Esa & Larasati, 2023; Noegraha et al., 2017). In addition, the functionality of applying bamboo to exterior and interior elements reinforces its perception as a reliable material in architectural design (Ameh et al., 2019; Dewi, N. et al., 2023). Aspects of design standards and government policies regarding the use of bamboo in construction also play an important role (Ekawati et al., 2022). In addition to technical factors, bamboo is considered more economical (Vijayalaxmi & Singha, 2021) and geographically accessible in some regions, making it an attractive option in development (Bredenoord, 2024; Wijewickrama et al., 2020). Cultural factors, social capital, and community perceptions also influence bamboo's image, as it is often associated with sustainability and innovation, although in some cultures it may be viewed as a simple material (Francois & Liaw, 2019; Rahmah et al., 2021). The psychological effects that arise from using bamboo, such as positive feelings towards a greener environment, also strengthen its appeal (Dewi, P., 2020).

The various perceptions formed influence people's preferences toward the use of bamboo. To increase this preference, educational approaches, research, and community service movements have proven effective (Maslucha et al., 2020; Maurina & Prastyatama, 2016). Hands-on practice, design visualization, and workshop-based learning systems that involve active participation are also effective in stimulating individuals' psychomotor and cognitive abilities related to bamboo materials (Bredenoord, 2024; Faisal & Kinasih, 2010; Putra & Prijotomo, 2016; Susanti et al., 2023; Wijewickrama et al., 2020). Research by Hoeffler & Ariely (1999) shows that preferences can change with variations in experience, and the more experience a person has, the more consistent and stronger their preference for an item becomes. This is also influenced by location differences, as found by Lee, J. (2019), and the more extensive the experience consumers have, the greater the potential for increasing their preferences (Czajkowski et al., 2015).

Much research has been conducted on the factors that influence people's perceptions and preferences toward bamboo, but it has yet to fully examine how these factors are formed and interact with each other. Therefore, this research aims to explore how strategies to optimize bamboo utilization among the community—through individual experiences and the learning that respondents have undergone—can positively shape their perceptions and preferences. Unlike formal education, the learning in this study refers to the knowledge and understanding that respondents acquire through real-life experiences, such as daily interactions with bamboo, exposure through media, and visits to bamboo structures.

It is hoped that this research will provide insights into effective approaches to enhance community engagement with bamboo, leading to more practical and targeted recommendations for encouraging the wider adoption of bamboo as a sustainable material in building construction.

2. METHODS

Data collection in this research was carried out in two stages. The first stage involved the use of an open-ended and multiple-choice questionnaire aimed at exploring individual and respondent attributes in greater detail. This questionnaire was created using Google Forms

and was available from March 2, 2024, at 12:50:02 WIB, to March 28, 2024, at 05:53:04 WIB, collecting responses from 131 participants. In the second stage, a closed-ended questionnaire incorporating an ordinal Likert scale, open-ended, and multiple-choice questions was distributed. This questionnaire, which included seven individual attribute questions and 87 closed-ended respondent attribute statements, was also designed via Google Forms and was available from May 10, 2024, at 10:00:45 WIB, to June 10, 2024, at 14:33:33 WIB, yielding 128 responses.

The first stage of analysis used a conventional content analysis approach based on the data collected by the researcher. Data obtained from the qualitative questionnaire results were processed through open coding, axial coding, and selective coding. The qualitative questionnaire consisted of (1) geographical domicile, (2) experience level categories based on bamboo utilization results, (3) perceptions formed, (4) preference categories in bamboo material utilization, and (5) reasons for preference. The results of the qualitative data were then further processed by adding a literature review using a directed content analysis approach related to bamboo materials from Frick (2004), Hidalgo López (2003), Minke (2012), and Dale's Cone of Experience (Lee, S. J. & Reeves, 2017).

The second stage of analysis, using the quantitative questionnaire framework, was conducted with closed-ended statements grouped into five core categories: (a) empirical experience, with 25 measurable variables; (b) passive and active learning process, with 8 measurable variables; (c) perception of bamboo material, with 15 measurable variables; (d) perception of interest and trust, with 16 measurable variables; and (e) application preference, with 22 measurable variables. The collected data was analyzed using principal component analysis (PCA) performed on all measured variables. The results of the factor analysis show that within the five core categories, there are latent variables for each category: (1) empirical experience, with 4 latent variables; (2) passive and active learning process, with 2 latent variables; (3) perception of bamboo material, with 4 latent variables; (4) perception of interest and trust, with 3 latent variables; and (5) application preference, with 3 latent variables. The identified factor groups were then further analyzed using regression analysis to determine the cause-and-effect relationships among the latent variables.

In this research, the cause latent variables consist of (1) empirical experience, with 4 latent variables; and (2) passive and active learning process, with 2 latent variables. Meanwhile, the effect latent variables consisted of (1) perception of bamboo material, with 4 latent variables; (2) perception of interest and trust, with 3 latent variables; and (3) application preference, with 3 latent variables. All these cause-and-effect latent variables are analysed using regression analysis to determine which cause latent variable has a significant influence on the effect latent variables. Regression analysis can be performed up to six to eight times, namely: (1) empirical experience and (a) bamboo material perception; (b) perceived attraction and trust; (c) application preference; (2) passive and active learning process and (a) bamboo material perception; (b) perceived attraction and trust; (c) application preference; (3a) bamboo material perception and application preference; (3b) perceived attraction and trust and application preference.

3. RESULT AND DISCUSSION

The results shown in Figure 1, which present the distribution analysis of the qualitative data, indicate that the most show that most respondents from both the first and second stages are distributed across provinces in Java.

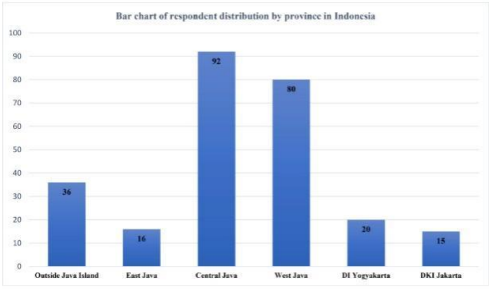

Figure 1. Bar Chart of Respondent Distribution by Province

A total of five variables, consisting of (1) geographical domicile, (2) categories of experience level based on bamboo utilization outcomes, (3) perceptions formed, (4) categories of preferences in the utilization of

bamboo materials, and (5) reasons for preferences, were processed using correspondence analysis and hierarchical clustering to examine the significance of how the variables influenced and affected each other. The results of the analysis indicate a statistically significant relationship between several pairs of variables, which can serve a basis for developing research hypotheses.

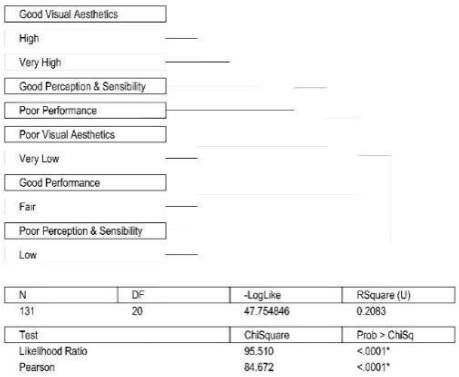

Figure 2. Correspondence analysis between experience level and formed perception

The most significant relationship was found between the variable of experience level and the perception formed with a Prob > ChiSq value of < 0.0001, as shown in Figure 2. This indicates that an individual's experience level greatly influences how their perception is formed; the higher the level of experience, the more positive the association with good aesthetic and visual factors, whereas the lower the level of experience, the more negative towards visual aesthetics.

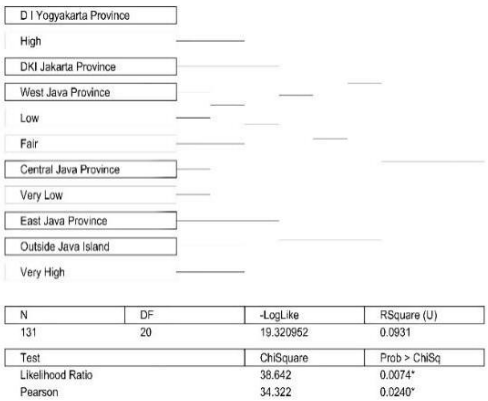

Figure 3. Correspondence Analysis Between Geographical Location and Experience Level

Furthermore, a significant relationship was also found between geography and experience level, with a Prob > ChiSq value of 0.0074, as shown in Figure 3. This indicates that a person's geographical location can affect their experience, with region outside Java Island generally exhibiting a higher intensity of experience.

Another significant relationship was between geographical location and category preference, with a Prob > ChiSq value of 0.0186, as shown in Figure 4. This indicates that the geographical context influences an individual's preference for a particular category, with respondents from regions outside Java and from DI Yogyakarta showing a greater interest in utilizing bamboo as a material for construction structures.

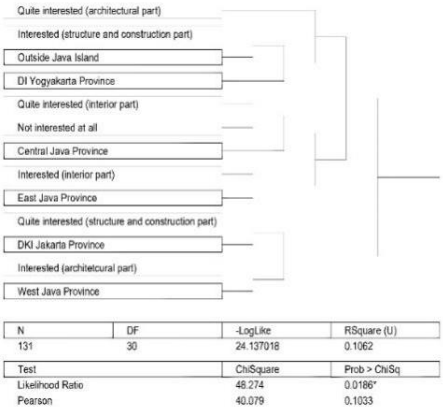

Figure 4. Correspondence Analysis Between Geography and Preference Categories

Additionally, a significant relationship was found between perceptions formed and preference type, with a Prob > ChiSq value of 0.0399, as shown in Figure 5. This indicates that the perceptions individuals hold can influence their preference for a particular type.

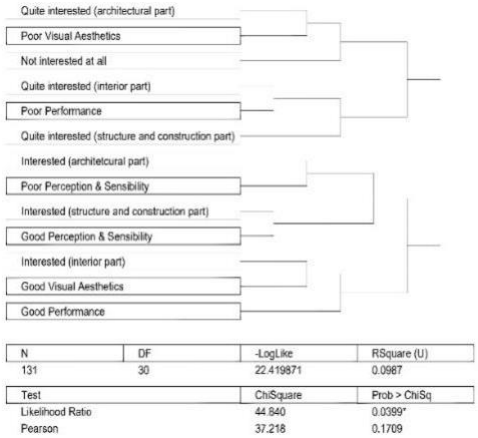

Figure 5. Correspondence Analysis Between Formed Perception and Preference Types

Some of the other variables tested in Figure 6 did not show a significant relationship, suggesting that these results may have occurred by chance. Based on the analysis, the hypothesis can be proposed that an individual's level of experience, which is influenced by their geographical location, significantly shapes perceptions. However, the perceptions that have already been forme, along with the geography of domicile, do not directly influence an individual's preference for bamboo materials. This hypothesis is supported by research from Czajkowski et al. (2015), Hoeffler et al. (2013), Bredenoord (2024), Faisal & Kinasih(2010), Maurina & Prastyatama (2016), and Susanti et al. (2023), wich highlight the significant effect on the perceptions of bamboo materials.

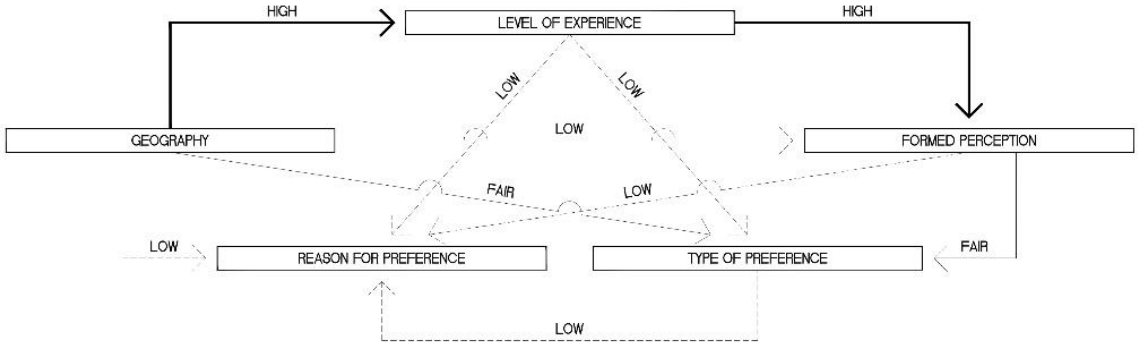

Figure 6. Correspondence Analysis Between Five Variables

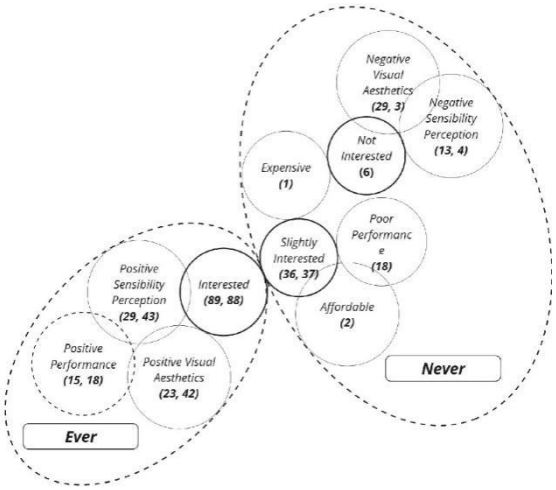

Figure 7. The Relationship Between Experience, Perception, and Interest in Using Bamboo

The diagram in Figure 7 illustrates how experience shapes perception and, in turn, influences a person's interest in using bamboo materials in building elements: (1) direct experience can positively influence perceptions, while (2) a lack of experience leads to disinterest due to concerns about affordability and poor visual aesthetics.

The hypothesis results and categories from the qualitative analysis were further examined with reference to research by (Alavi et al., 2020) and followed by regression analysis. The next step involved conducting factor analysis (FA) to identify latent variables (dimensions). Five main categories were generated: empirical experience with 25 variables, learning experience with 8 variables, material perception with 15 variables, material attraction with 16 variables, and application preference with 22 variables. Based on the results of Principal Component Analysis (PCA) and Factor Analysis (FA), it was found that there are two cause dimensions and three effect dimensions, as illustrated in Figure 8. These dimensions were then analyzed using multivariate regression analysis to assess the influence of causation between the five dimensions.

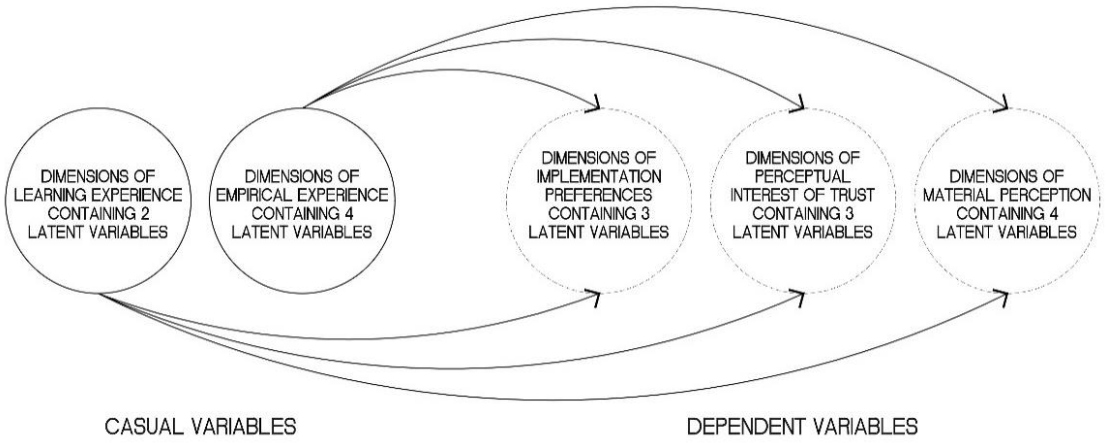

Figure 8. Regression Flow Relationship

Regression analysis yielded several insights into the influence of empirical experience and learning experience on bamboo material perception. Firstly (1a), Perceived Sensibility showed a positive influence from empirical experience with a p-value of 0.0063*, indicating that exposure to bamboo in architectural daily life-such as furniture, crafts, installations, and small-scale bamboo buildings-increased sensitivity to bamboo's unique, natural, and aesthetic characteristics. Secondly (2a), learning experiences through passive learning methods also had a significant effect, with a p-value of 0.0243*, strengthening understanding of the uniqueness and beauty of this material. Thirdly (3a), Perceived Familiarity was significantly influenced by the learning experience, with a p-value of 0.0009*, suggesting that passive learning approach can increase familiarity and inclusiveness toward bamboo as an economical material. Lastly (4a), Perceived Sustainability also showed a significant influence from empirical experience with a p-value of 0.0035*, indicating that interaction with bamboo in architectural daily life can enhance positive views regarding the eco-friendly nature and abundant availability of bamboo.

Regression analysis of the influence of empirical experience and learning experience on Perceived Trustworthiness led to several conclusions. Firstly (1b), Perceived Durability Performance is significantly influenced by empirical experience, with a p-value of 0.0384*, indicating that experience with bamboo for construction contributes to a positive view of its strength and durability. Secondly (2b), learning experience through passive methods also had a significant influence, with a p-value of 0.0177*, reinforced beliefs in the ease of maintenance and disaster resillience of bamboo. Thirdly (3b), Perception of Architectural Construction, there was a significant effect of empirical experience with a p-value of 0.0228*, indicating that interaction with bamboo in daily architectural contexts increased positive views on its applicability in design. Fourthly (4b), learning experience also showed a highly significant influence, with a p-value of 0.0002*, indicating that structured learning methods can enhance understanding of bamboo’s potential as a construction material. Fifthly (5b), Perception of Artwork showed highly significant results for both variables. Empirical experience with a p-value of 0.0004* indicates that exposure to bamboo in an artistic context contributes to a positive assessment of its artistic qualities. Finally (6b), learning experience with a p-value of <0.0001* confirmed that passive learning approach effectively increased interest in and trust toward bamboo as an artistic material.

Regression analysis of the influence of empirical experience and learning experience on preference for application of bamboo materials led to several conclusions. Firstly (1c), on structural construction element preferences, learning experience showed a significant influence, with a p-value of 0.0409*, indicating that the passive learning approach contributed to the interest in applying bamboo

in various structures. Secondly (2c), preference for architectural furniture elements was significantly affected by empirical experience, with a p-value of <0.0001*, indicating that direct exposure to bamboo in daily architectural life increased interest in using bamboo for making chairs, tables, and cupboards. Thirdly (3c), learning experience through active learning method also showed a positive influence, with a p-value of 0.0050*, increasing understanding and interest in creating bamboo furniture. Fourthly (4c), on decorative element preference, empirical experience has significant influence with a p-value of 0.0106*, indicating that interaction with bamboo in architectural daily life increases interest in applying bamboo for decorative elements. Figure 9 illustrates how the cause-and-effect variables influence each other.

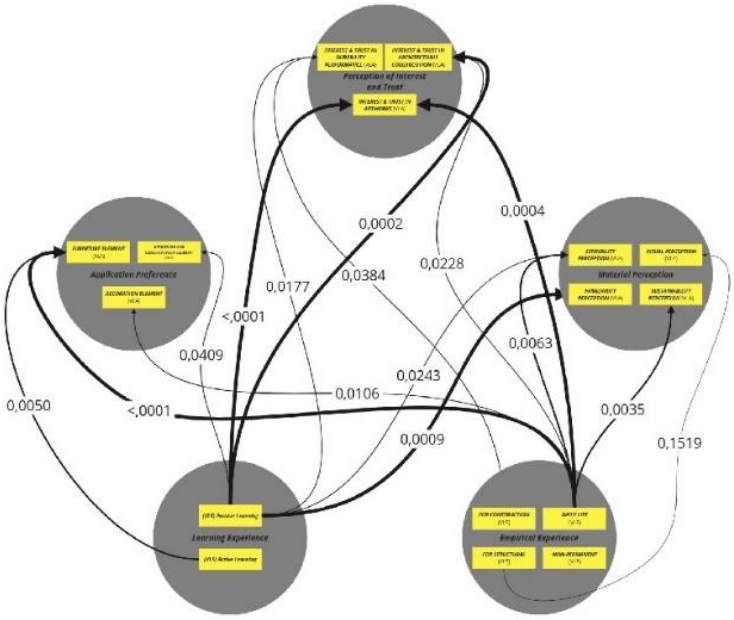

Figure 9. Visualization of The Flow of Regression Results

In more detail, the results of the regression analysis showed that: (1) empirical experience in an architectural context, such as interaction with bamboo in musical instruments, furniture, and small-scale buildings, significantly increased sensibility towards bamboo aesthetics (p-value 0.0063) and strengthened perceptions of bamboo's sustainability (p-value 0.0035). Empirical experience in construction, such as bamboo wall and roof trusses, also strengthened perceptions of bamboo's resilience (p-value 0.0384) and applicability in architectural design (p-value 0.0228), as well as increasing judgments of its artistic qualities in art (p-value 0.0004). In addition, everyday empirical experiences increased interest in applying bamboo to architectural furniture elements, such as chairs and tables (p-value < 0.0001), as well as in decorative elements like wall hangings and lamps (p-value 0.0106). On the other hand, (2) learning experiences, particularly through passive learning approaches, such as reading, listening, or visiting bamboo buildings, strengthened understanding of bamboo aesthetics (p-value 0.0243) and increased familiarity with bamboo as an economical material (p-value 0.0009), along with beliefs in its durability and responsiveness of bamboo to disasters (p-value 0.0177). Passive learning also contributed to hightened interest in applying bamboo in structural construction elements, such as floor trusses, columns, and roof trusses (p-value 0.0409), as well as strengthened understanding of bamboo's potential as a construction material (p-value 0.0002). On the other hand, active learning, such as participating in workshops or living in bamboo buildings, increased interest in creating bamboo furniture (p-value 0.0050).

Results of this study, the most significant were empirical experiences that increased interest in applying bamboo to architectural furniture (p-value <0.0001), learning experiences through

passive learning that strengthened understanding of bamboo's potential as a construction material (p-value 0.0002), and empirical experiences in the context of art that significantly increased assessment of bamboo's artistic qualities (p-value 0.0004).

The results of the quantitative analysis support most of the hypotheses proposed in the qualitative analysis and some of the literature in the introduction. The influence of Empirical Experience on Perceptions that direct experience of bamboo applications increases perceptions of the aesthetics, sustainability and durability of the material is supported by the literature which states that direct experience influences one's perception of materials (Hoeffler et al., 2013). Additionally, literature from (Xinping et al., 2018; Vijayalaxmi & Singha, 2021) supports positive perceptions of bamboo's strength and resilience. The role of an educational approach suggests that passive learning that increases understanding of bamboo's construction potential and familiarity as an economical material is in line with literature reviews (Maurina & Prastyatama, 2016; Faisal & Kinasih, 2010) that demonstrate the effectiveness of workshop-based educational approaches in improving individuals' cognitive abilities towards bamboo materials.

The influence of empirical experience is higher than the influence of passive learning on preferences. This is shown in the findings that preferences for furniture elements (p-value <0.0001) and decoration elements (p-value 0.0106) are more influenced by empirical experience, while preferences for structure and construction elements (p-value 0.0409) are more influenced by passive learning; which is consistent with the literature which states that variations in experience, both direct and indirect, have different influences on individual preferences (Hoeffler et al., 2013; Hoeffler & Ariely, 1999). An individual's level of experience proved to be a significant influence in shaping perceptions, consistent with the initial hypothesis. Furthermore, preference for bamboo was determined more by the type of experience (empirical or educational) than by pre-formed perceptions, supporting the hypothesis that perception indirectly influences preference. A review of the literature suggests that geographical location has an effect on preference (Lee, J., 2019; Lee, S. J. & Reeves, 2017).

In addition, Dale's Cone of Experience concept suggests that although active learning has an influence, passive learning tends to have a more profound effect on public understanding, mainly because it reduces reliance on concrete experiences alone to generalize insights (Lee, J., 2019; Lee, S. J. & Reeves, 2017; Seels, 1997). This also reflects Dale's (1969) view on the importance of a balance between concrete and abstract experiences. The clusters identified in this study show variations in sensitivity to bamboo aesthetics, which emphasizes the importance of marketing strategies that highlight the aesthetic aspects of this material, in line with recommendations from research by (Bredenoord, 2024; Vijayalaxmi & Singha, 2021) on the importance of tailoring public perception. Research from (Hoeffler et al., 2013) highlights that experiential variations in learning strategies can be more effective in promoting acceptance of bamboo as an alternative construction material. The results of this study, therefore, provide insights into understanding the relationship between public experiences, perceptions and preferences towards bamboo, and guide the development of policies and practices that better support sustainable development.

4. CONCLUSION

This research underscores the transformative impact of experiential learning on community perceptions and preferences, offering practical recommendations to promote bamboo utilization. By integrating bamboo into everyday life through architectural furniture and artwork, and by fostering passive learning opportunities such as exhibitions, media campaigns, and educational initiatives, the untapped potential of bamboo as a sustainable and aesthetic material can be effectively realized. A multifaceted approach that combines passive education, experiential learning, and active participation is key to promoting the wider adoption of bamboo in architectural design and everyday applications.

The recommendations of this research include several aspects that can support the wider

utilization of bamboo. In architectural education, it is recommended to integrate bamboo more deeply in the curriculum, both from technical construction aspects and in the context of art and design. Hands-on experience through field trips and workshops on making or applying bamboo in design projects will enrich students' understanding. In the area of community service, it is important to encourage further research on the benefits of bamboo in construction, as well as conduct community service programs focusing on bamboo-based projects to enhance sustainability awareness within communities. For architectural practitioners, an effective strategy includes demonstration projects using bamboo and visual promotion through exhibitions and social media to showcase the advantages of this material. For stakeholders and policies, the government is encouraged to develop global bamboo ISO guidelines contextualized for Indonesia, and to mandate no-cost certification assessment on agreed standards for bamboo buildings in Indonesia.

Some recommendations for future research include applying Vygotsky's Zone of Proximal Development (ZPD) concept, which emphasizes the importance of social interaction and collaboration through experienced mentors (Eun, 2019). In addition, the application of Kolb's Learning Cycle can also enhance the understanding of knowledge by combining concrete experience, reflection and active testing through real projects (Hansen, 2000; Wijnen-Meijer et al., 2022; Yusof et al., 2020), thus providing a more comprehensive insight into how individuals learn and interact with bamboo in the context of architecture and sustainable development.

AUTHORS CONTRIBUTION

Vinsensius Gilrandy Santoso contributed to the research's topic, research concepts, preparation, methodologies, investigations, data analysis, visualization, articles drafting, and revisions.

Suhendri contributed to manage preparation, methodology, and supervision.

Dewi Larasati contributed to methodology, supervision, review, and validation.

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