

## **EMPIRICAL DEMONSTRATION OF FIRE-RETARDANT BAMBOO TO JUNIOR HIGH SCHOOL STUDENTS FOR IMPROVING UNDERSTANDING OF PHYSICOCHEMICAL PROPERTIES OF ORGANIC MATERIAL**

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### **Abstract**

This research aims to demonstrate the change in properties of bamboo due to the coating process to students and to decide the science teaching results in junior high school students respecting the physicochemical properties of organic material by utilizing fire-resistant bamboo teaching materials. The fire-retardant bamboo experiment was carried out by spraying anti-flame paint on pieces of bamboo fiber, burning the bamboo, and observing the changes. The morphology of bamboo is observed. Besides that, the learning is managed using empirical demonstration methods for 20 students in three phases: a pre-test; granted a didactic video, and a post-test. The results showed that an anti-flame paint coating strengthened the bamboo layer. After spraying the fire-retardant liquid, a protective layer will form on the bamboo. This layer protects the bamboo components, such as carbon, hydrogen, and oxygen; therefore, the heat emitted by the fire does not react with the bamboo components. The heat will react with the elements in the anti-flame layer and form carbon dioxide, which keeps the fire from growing and does not burn the bamboo layer. The teaching results using the fire-retardant bamboo experiment through the empirical demonstration method effectively improve student teaching results because the median post-test grade after the video demonstration is greater than the pre-test. This study helps know changes in the properties that occur in bamboo before and after the coating process and is an alternative teaching material that teachers in teaching changes in the properties of a material can use.

Keywords: Bamboo, Coating process, Fire retardant paint.

## **1. Introduction**

Bamboo is known as the fastest-growing plant in the world, abundant in Indonesia. Bamboo can grow up to 60 cm or more days and go up to 40 m. That makes bamboo to be the world's fastest-growing plant. Bamboo has good bending strength and flexibility. It is also a lightweight, flexible, rigid, highly malleable, low-cost material, and multifunction in building works [1]. Bamboo has multiple benefits compared to other construction materials; therefore, bamboo should be broadly used, especially in construction. However, the nature of bamboo, which is not fire-resistant or flammable, is one of the weaknesses that limit the application of bamboo, especially in the construction sector [2]. Bamboo also has electrostatic properties, which can lead to a risk of explosion if used for storage rooms for flammable chemicals [3]. Bamboo consists of carbon (50%), hydrogen (6%), and oxygen (44%) [4]. These components are bonded to each other and will break when reacting with fire to form new compounds in the form of steam. The steam or gas will react with oxygen from the air and cause the combustion to get bigger, eventually producing residual discharge in the form of carbon dioxide and water vapor.

Previous studies coated the bamboo surface through a coating process to overcome these. The coating process on bamboo will form a layer that can extend its life by protecting the substrate from electrostatic currents, U.V. rays, mechanical damage, chemicals, and organisms such as fungi. Generally, the coating process consists of several steps: substrate drenching, aligning, infiltration, and draining into the coating [5]. The material used as a coating is fire retardant paint. Several paints are catalyzed components, nitrocellulose, and acrylic lacquers [6]. These paints can be made of resin or amine-based [7], nitrocellulose resin [8], and polyurethane-acrylate resin [5]. This bamboo coating process can be an alternative experiment for learning properties and materials at the first school level. In general, experiments to study material properties only identify the physical properties of a material. With this experiment in the bamboo coating process, the investigations carried out can represent changes in the properties that occur in a material; namely, bamboo becomes stronger and fire-resistant.

The learning method that can be used to teach the fire-retardant bamboo coating process to students is an empirical demonstration teaching method. This method is performed by conducting experiments using materials easily found by students in the surrounding environment [9]. Several previous studies have shown that applying empirical demonstration learning methods increases student focus and helps students understand the material being taught [10]. In addition, this method can help students with slow learning who feel left behind. They can focus more on capturing the theory being learned [11]. Another research showed that the empirical demonstration learning method increased students' interest in learning and teaching results [12]. Therefore, this method can support implementing a fire-retardant bamboo coating process in science learning that has never been done before.

This research purpose was to demonstrate the change in properties of bamboo due to the coating process to students and to figure out the junior high school students' science learning results respecting the physicochemical properties of organic material by utilizing fire-resistant bamboo teaching materials. In this research, the experiments were assisted in two parts: bamboo fire retardant experiments and the teaching process. The first section is the comprehension of the bamboo fire retardant experiment. This part will explain the process of coating

bamboo using fire retardant paint. After that, the fire-resistant and ordinary bamboo were burned to compare the changes in the bamboo's characteristics. Adjustments in the bamboo's properties can be studied further by conducting the test using an I.R. spectrophotometer and TG/DTA.

In the second section, learning using fire-retardant bamboo is implemented for students using an empirical demonstration teaching process. The empirical demonstration teaching process is applied through the pre-test, didactic videos, and post-test presentation. Didactic video media is chosen because it can represent information or events without having to go through them first-hand. It is proposed that the method would help in demonstrating specific skills, promote explanation, and improve teaching skills; therefore, it will have a good influence on students and will be able to increase student teaching results.

## **2. Material and Method**

### **2.1. Material**

The study materials used are pieces of bamboo stripes (purchased from a Market in Bandung, Indonesia) and fire-retardant paint (purchased from a Market in Bandung, Indonesia).

### **2.2. Fire-retardant bamboo experiment method**

The experiment was carried out by spraying anti-flame paint on pieces of bamboo fiber and waiting for the paint to dry. The painting process is repeated until the bamboo layer is entirely covered. After that, prepare the painted bamboo and unpainted plain bamboo. The two bamboos were weighed using an analytical balance to determine their mass. After that, the two bamboos were burned simultaneously for one minute, and the changes were observed. The maximum adsorption yield and absorption peak of the bamboo fire retardant and plain bamboo were measured and compared using an infrared spectrophotometer (FTIR). In addition, the weight change of fire-retardant bamboo and plain bamboo was measured using thermogravimetry/differential thermal analysis (TG/DTA). Detailed information on the way how to use TG/DTA and FTIR is shown in previous studies [13-15].

### **2.3. Treatment procedure**

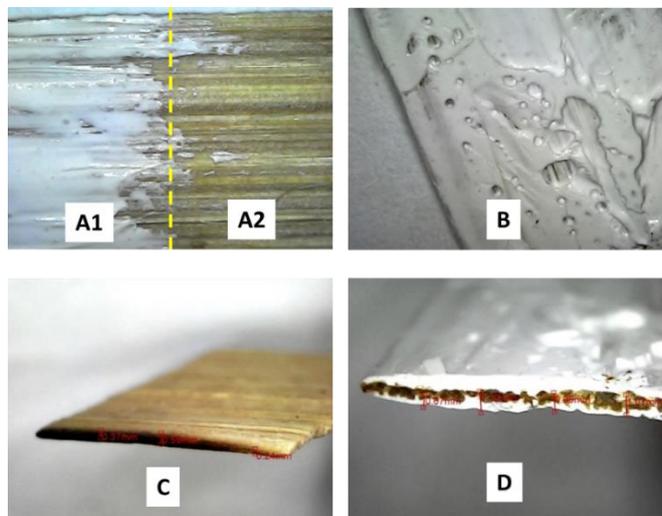
The research was performed using an empirical demonstration method as the teaching method. The participants in this research were 20 students from a junior high school in Jakarta, referring of five male students and 15 female students. The application of fire-retardant bamboo learning material is performed in several phases. The first phase is giving a pre-test before learning using the didactic video. Next, the fire-retardant bamboo learning material through a didactic video is presented to explain the physicochemical properties changes in bamboo due to combustion. Finally, students need to accomplish a post-test after participating in learning. The pre-test and post-test questions contain 20 true or false questions. The correct answer is allowed a five score, and the incorrect answer is 0, with 100 as the maximum score. The teaching results are analysed using gain calculations. This analysis was done to know the differences in teaching results before and after using fire retardant bamboo as learning material in explaining the physicochemical properties of organic material. In addition, this analysis was realized to figure out the significance level of the

empirical demonstration learning method. Students' I.Q. scores as their primary information are collected before learning to support the research instrument.

### 3. Results and Discussion

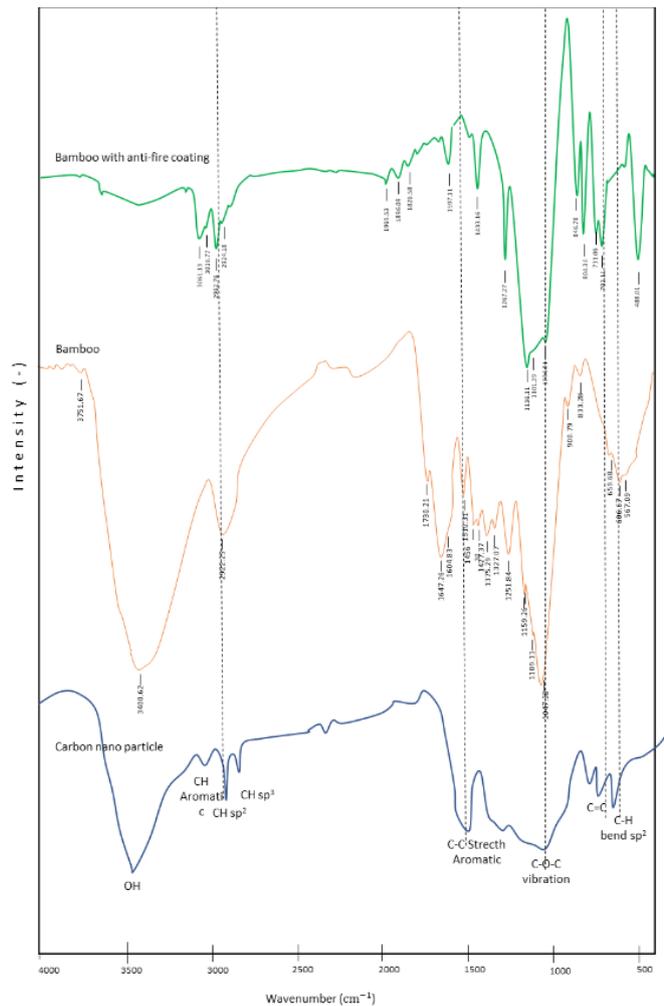
#### 3.1. Bamboo morphology

Figure 1(a) shows the bamboo surface morphology before and after coating. Then, bamboo that has not been coated with paint shows a layer of fiber, as shown in Fig. 1(a2). Meanwhile, bamboo fibers do not appear, and the surface becomes thicker on bamboo coated with paint, as shown in Fig. 1(a1). The thickness measurement of bamboo is shown in Figs. 1(c) and 1(d). Figure. 1(c) shows that the thickness of bamboo that has not been coated with paint is 0.40 mm. Figure. 1(d) shows that the thickness of bamboo covered with paint is 0.96 mm. Then, the thickness of the coating layer formed is 0.56 mm. After testing the fire resistance by burning the bamboo coated with paint for 1 minute, the results are shown in Fig. 1(b). The coating layer on the bamboo looks a little melted but can still protect the bamboo layer well. It can be caused by paint drying that has not been maximized so that the coating layer has not been formed properly. After spraying the fire-retardant paint, a protective layer will begin on the bamboo. This layer protects the bamboo components, such as carbon, hydrogen, and oxygen. Therefore, the heat emitted by the fire does not react with the bamboo components. The heat will react with the elements in the anti-flame layer and form carbon dioxide, which keeps the fire from growing and does not burn the bamboo layer. The coating of bamboo with fire-resistant liquid changes its properties of bamboo. The surface layer of the bamboo will become denser, so the bamboo will become stronger. A formulation of acrylic latex and nitrocellulose resin in fire-retardant latex and alkyd-based paint can reduce the flame spreading of the gas phase and catalyse the decomposition of the material's surface to form non-volatile char in the condensed phase [16].



**Fig. 1. Bamboo Morphology: after (a1) and before (a2) coating process, after combustion process (b), and the thickness of bamboo before coating (c) and after coating (d).**

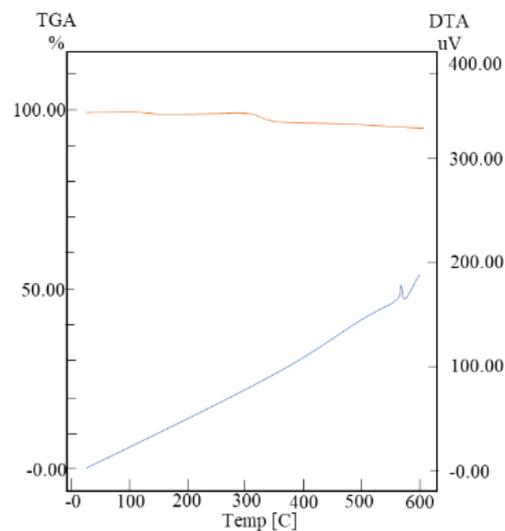
FTIR can be used to describe organic and inorganic compound interaction and analyse the function group of different elements [17]. Detailed information for the FTIR analysis is shown in the previous study [18]. Figure 2 shows the FTIR spectra of plain bamboo, bamboo with fire retardant coating, and carbon nanoparticles. Based on FTIR results, there is a C-O stretching vibration at  $1047.36\text{ cm}^{-1}$  in plain bamboo, indicating the presence of cellulose content in bamboo [19]. The absorption band at  $1510.31\text{--}1730.21\text{ cm}^{-1}$  shows the lignin region [20]. The absorption peak at  $1730.21\text{ cm}^{-1}$  indicates a non-conjugated C=O stretching in the hemicellulose trying vibration absorption peak [21]. There is a C-C stretching aromatic at  $1510.31\text{ cm}^{-1}$  [20]. The absorption peak at  $1253.77\text{ cm}^{-1}$  shows the syringyl units in bamboo [21]. It also indicates peaks at  $2922.25$ ,  $3400.62$ , and  $1647.26\text{ cm}^{-1}$  corresponding to the C-H stretch, the vibration O-H, and the conjugated carbonyl stretching [20]. In addition, there are peaks at  $606.67$ ,  $659.68$ , and  $2922.25\text{ cm}^{-1}$  corresponding to the C-H bend  $\text{sp}^2$ , the C=C bond, and the C.H.  $\text{sp}^2$  [22].



**Fig. 2. The FTIR spectra of plain bamboo, bamboo with fire retardant coating, and carbon nanoparticles.**

Meanwhile, the spectra of bamboo with fire retardant coating showed that the coating process on the bamboo caused several peaks to shift. The C-H bend  $sp^2$  peak moved to  $488.01\text{ cm}^{-1}$ . The C=C bond peak went to  $702.11\text{ cm}^{-1}$ . The C-O stretching vibration turned to  $1036.81\text{ cm}^{-1}$ . The C-C stretching aromatic moved to  $1433.16\text{ cm}^{-1}$ . The CH  $sp^2$  bond turned to  $2962.76\text{ cm}^{-1}$ . The vibration O-H peak went to  $3061.13\text{ cm}^{-1}$ . In addition, several peaks indicate the composition of fire-retardant paint, such as nitrocellulose, butyl acrylate, styrene, and acrylic acid. The  $\text{NO}_2$  vibration peaks at  $1597.11$ ,  $1267.27$ , and  $846.79\text{ cm}^{-1}$  indicated the presence of nitrocellulose [23]. The content of butyl acrylate is known from the C=O vibration peak at  $1826.58\text{ cm}^{-1}$  and the C-O vibration peak at  $1136.11\text{ cm}^{-1}$ [23]. The absorption peak of monosubstituted C-H at  $731.06\text{ cm}^{-1}$  indicated the presence of styrene [23]. The vibration O-H peak at  $3061.13\text{ cm}^{-1}$  indicates the presence of acrylic acid [23].

Fire-resistant paint can increase the mechanical strength and heat resistance of bamboo. Thermogravimetry and Differential Thermal Analysis (TG-DTA) are used for concurrent thermogravimetric and differential analytical measurements on fire-resistant bamboo. Figure 3 represents the TG-DTA analysis of fire-retardant bamboo. The T.G. analysis showed changes in the mass during the heating process, whereas the D.T.A. analysis detected some exothermic reactions [21]. On set is reached at a temperature of  $568.31^\circ\text{C}$ . It indicates no significant loss in the weight of the sample until the temperature reaches  $568.31^\circ\text{C}$ . Exceeding the onset temperature, a slight loss in the sample weight started from  $534.72^\circ\text{C}$ . It can be based on the combusting end of the complex up to the endpoint temperature of  $595.18^\circ\text{C}$  [24].  $95.68\text{ wt}\%$  of the mass reduction happened due to lignin degradation [25]. No mass reduction was found at temperatures higher than  $596^\circ\text{C}$ , indicating that the organic components had been fully converted into ash with a final mass of  $4.32\text{ wt}\%$  [22]. The D.T.A. curve of the complex shows an exothermic peak at  $576.68^\circ\text{C}$  coincides with the disintegration process of the residual organic materials [24]. It differs from common organic material, which will be burned and converted into carbon at  $200^\circ\text{C}$  [14].

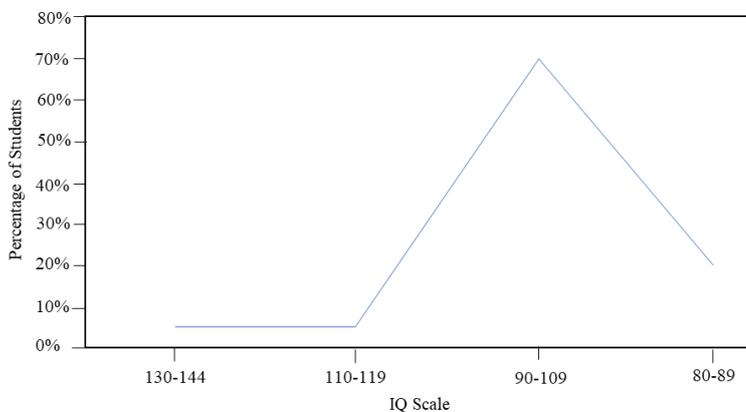


**Fig. 3. TGA/DTA curve of fire-retardant bamboo.**

### 3.2. Students' demographic

Figure 4 shows the demographic data of 20 students, which contains information about students' I.Q. scores. This demographic data is required to establish the extent to which students' cognitive abilities in processing study. The graph shows that 5% of students have I.Q. scores in the 130-144, classified as gifted or very advanced. Students in this group tend to have developed cognitive abilities; therefore, students are usually very fast in processing learning. Students have an I.Q. score of 110-119; there are as many as 5%. Students in this range are classified as high average, which means students have above-average cognitive abilities and can process learning quickly. As many as 70% of students have I.Q. scores in the 90-109. Students in this range are classified as average, which means students have average cognitive abilities.

At last, 20% of students have I.Q. scores in the 80-89. Students in this range are classified as low average, which means students in this range have cognitive abilities below the norm; therefore, students tend to be slow in processing learning. The interpretation of the I.Q. score range above is based on the Stanford Binet scale [26].



**Fig. 4. The students' demographic data.**

### 3.3. Teaching process

The morphology investigation of prepared carbon particles was analysed using Digital Microscope (BXAW-AX-BC, China). Table 1 presents the analysis results of the students' answers regarding changing the material properties taught. Twelve concepts on the questions could be mastered by 85% of the students. However, there are eight concepts in the problem that students have not been able to master, especially the concepts regarding the composition of bamboo and the function of the chemical components in bamboo. It happens because students find it challenging to remember the name of the bamboo's composition and the chemical elements in bamboo. Even so, there was a relatively high increase in answers to these two concepts after the learning. Overall, there was an increase in students' correct answers after learning using the fire-retardant bamboo experiment. However, there is a decrease in the correct answers on the impact of combustion compounds effect and the effect of the reaction between anti-flame paint and bamboo concepts. This decrease could occur because the questions were randomized at the time of the post-test; therefore, students were fooled when answering.

**Table 1. The analysis results of the student's answers.**

No.	Concept on Problem	Number of Students Who Answered Correctly	
		Pre-test	Post-test
1	The properties of a material	19	20
2	Chemical properties of a material	10	15
3	Physical properties of a material	15	20
4	Bamboo as an alternative construction material	18	19
5	Physical properties of bamboo	9	17
6	Physical properties of bamboo	6	17
7	Chemical properties of bamboo	18	20
8	Bamboo composition	2	10
9	Chemical components in the composition of bamboo	20	20
10	The function of the chemical components in bamboo	3	11
11	Weaknesses of bamboo	15	17
12	The combustion process that occurs in bamboo	6	12
13	Impact of combustion compounds	17	13
14	Types of compounds resulting from combustion	17	18
15	Introduction of fire-resistant paint	16	18
16	Use of fire-retardant paint on bamboo	9	12
17	The reaction process between fire-resistant paint and bamboo	16	18
18	Effect of reaction between fire retardant paint and bamboo	17	16
19	Effect of anti-flame liquid on the physical properties of bamboo	11	15
20	Changes like bamboo	13	17

The students' pre-test and post-test scores are shown in Table 2. Before using the fire-resistant bamboo experiment in learning, the student teaching results average score in the pre-test was 64. The average score of teaching results increased to 80.75 after implementing learning using the fire-retardant bamboo experiment. It shows that the empirical demonstration method is effectively applied in learning. This method can explain each stage in the testing process in more detail even though students are not directly involved in the experiment. It follows the earlier studies' results, which stated that the empirical demonstration method helps students relate the investigations carried out to the science concepts being taught. Therefore, science becomes more relatable to the surrounding environment, and students will more easily understand the vision. Practical demonstration learning that is applied through learning videos can explain the concept of changing the properties of bamboo due to the excellent coating process to students. The fire-retardant bamboo experiment that was carried out interestingly can be presented: therefore, students focus more on understanding and implementing the concepts being taught. It follows previous reports [10, 11], which explain that the empirical demonstration method can develop student focus on learning.

In this study, students cannot be directly involved in experiments because of online-based teaching. Therefore, this learning video will help them give an

accurate picture of the experimental process without experimenting. The didactic videos provide an exciting display and help explain the process of making ionic liquids more clearly. In addition, students can repeat the video continuously if they do not understand the lesson [27]. Learning videos are also easily accessible by students, making it easier for them to distance learning [27]. However, some students do not experience changes in teaching results and a decrease in teaching results based on the acquisition of N-gain. Students who do not experience differences in teaching results are classified as having moderate and low cognitive abilities based on I.Q. scores. Therefore, they need a longer time to process learning. They still get good teaching results despite no increase in teaching results. Based on their I.Q. scores, students who experience decreased teaching results have low cognitive abilities. Therefore, they had little difficulty processing learning because learning using the fire-resistant bamboo experiment was new.

**Table 2. The pre-test and post-test scores of students**

Student	Pre-test	Post-test	Gain
1	65	100	1
2	40	45	0.083
3	70	95	0.833
4	75	70	-0.2
5	70	85	0.5
6	50	60	0.2
7	60	100	1
8	60	90	0.75
9	65	85	0.57
10	60	70	0.25
11	60	90	0.75
12	80	80	0
13	45	60	0.3
14	75	85	0.4
15	75	70	-0.2
16	60	80	0.5
17	60	75	0.375
18	65	95	0.86
19	90	90	0
20	55	90	0.8
<b>Average</b>	64	80.75	0.5

#### 4. Conclusions

After doing research, it can be concluded that the coating process using fire-resistant paint can cause changes in the properties of bamboo to become stronger and denser. The coating layer protects the components that make up the bamboo. Therefore, they do not react to the heat from the fire. The heat of the fire will react with the coating layer to form carbon dioxide so that the bamboo does not burn. The teaching results using the fire-retardant bamboo experiment through the empirical demonstration method effectively improve student teaching results because the average post-test score after the video demonstration is greater than the pre-test score. The fire-retardant bamboo experiment that was carried out interestingly can be presented. Therefore, students focus more on understanding and implementing the concepts being taught.

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