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Students' Creative Thinking Skills on Green Chemistry by Designing Fire-Reterdant Bamboo

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Abstract: This study aims to reveal students' creative thinking skills through the implementation of fire-retardant bamboo learning designs using ionic liquids that integrate chemical bonding materials and polymers. This research method is qualitative research. The research was conducted in class XII of SMA N Cibinong for two meetings with 36 students. The instruments used were observation sheets and video-audio recordings. The data obtained was analyzed using the transcript based lesson analysis method to determine the profile of students' creative thinking abilities. The creative thinking indicators used are five creative thinking indicators according to Munandar (1992). The percentage of indicators of creative thinking skills that appear the most in the first and second meetings is the indicator of fluency as much as 60.1% in the first meeting and as much as 62.1%. While the indicator with the least percentage of appearances at the first and second meetings is the originality indicator of 3.2% at the first meeting and as much as 0.1% at the second meeting learning activities.

Keywords: green chemistry, creative thinking skills, transcript base lesson analysis.

Abstrak: *Penelitian ini bertujuan untuk mengungkap kemampuan berpikir kreatif siswa melalui desain pembelajaran bambu tahan api dengan memanfaatkan cairan ionik yang diintegrasikan pada materi ikatan kimia dan polimer. Metode penelitian ini adalah penelitian kualitatif. Penelitian dilakukan di kelas XII salah satu SMA N Cibinong selama dua kali pertemuan dengan jumlah siswa sebanyak 36 orang. Instrumen yang digunakan berupa lembar observasi dan rekaman vidio-audio. Data yang didapatkan dianalisis dengan metode transkript based lesson analysis untuk mengetahui profil kemampuan berpikir kreatif siswa. Indikator berpikir kreatif yang digunakan adalah lima indikator berpikir kreatif menurut munandar (1992). Persentase kemuculan indikator keterampilan berpikir kreatif yang paling banyak pada pertemuan pertama dan kedua adalah indikator berpikir lancar sebanyak 60,1% pada pertemuan pertama dan sebanyak 62,1%. Sedangkan indikator dengan persentase kemunculan paling sedikit pada pertemuan pertama dan kedua adalah indikator orisinalitas sebanyak 3,2 % pada pertemuan pertama dan sebanyak 0,1% pada pertemuan kedua.*

Kata kunci: *kimia hijau, keterampilan berpikir kreatif, transcript based lesson analysis.*

▪ INTRODUCTION

The increasing human population has an impact on the number of buildings produced. As a result, construction materials and construction processes have also improved. The most common construction materials used by humans are concrete and cement. Due to the increased use of these materials, the production of concrete and cement has also increased. However, the production of concrete and cement significantly contributes to pollution and global warming by trapping greenhouse gases during production into the atmosphere (Prajapati & Dua, 2022). This prompted researchers to focus on unconventional construction materials that can be used as a substitute for concrete (Borowski, 2021). As a result, the use of natural production and

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construction materials has attracted interest associated with the desire to develop greener or environmentally friendly processes.

Bamboo, which is also known as a group of perennial grasses with woody stems, is increasingly attracting attention as a natural material that can be used to meet construction needs and as a substitute for conventional construction materials of concrete and cement. (Javadian et al., 2020). Worldwide, bamboo consists of 118 genera with about 1482 species (Nath, 2020). Bamboo has a characteristic that the stem is mostly hollow and there are segments with internodes (Wong, 2004). Bamboo products have been suggested to have positive environmental impacts and distinctive social and economic benefits (Shen et al., 2019). This is because bamboo has several advantages such as a fast growth period (it can be harvested selectively after 3-4 years) (Liese & Michael, 2015) Bamboo is a plant that can regenerate through new shoots that appear every year (Akinlabi, 2015). However, despite the several advantages possessed by bamboo, bamboo has the disadvantage of being flammable.

The combustibility of bamboo is due to the fact that most of the bamboo constituents are polymers which are very sensitive to flames. The components that make up bamboo in the form of carbon, hydrogen and oxygen if there is sufficient air and a fire will cause these chemical elements to decompose into flammable CO, CO2, H2 and CH4 gases. (Dayadi, 2021). In addition, bamboo has flammability which is also caused by hollow bamboo stems (Miyafuji, 2015). The flammable nature of bamboo makes the use of bamboo less than optimal and dangerous for humans. One way to overcome the weakness of flammable bamboo is to use ionic liquids.

Ionic liquids are salts that are liquid at room temperature (Marcus, 2016). Ionic liquids have a low melting point, which is below 100OC (Nurdiah. 2016). The ionic liquid used will disrupt the interaction of the cellulose intermolecular bonds by means of cations attacking the O atom from the –OH group and anions attacking the H atom from the –OH group (Zhang, 2017). One of the ionic liquids that can be used as a fire retardant for bamboo is 1-ethyl-3-methylimidzolium hexafluorophosphate (Miyafuji, 2013) because cellulose-based fibers have hydroxyl groups, they can be effectively suppressed with phosphorus-based flame retardants. During the thermal decomposition process, phosphorus-based flame retardants can dry out cellulose (Salmeia, 2016). Ionic liquids are considered as environmentally friendly compounds or green chemistry because they can be recycled, their high thermal stability properties, and negligible pressure at room temperature make ionic liquids non-volatile so that no vapor release occurs into the atmosphere (Flieger & Flieger, 2020). Green chemistry has 12 principles as design guidelines design guidelines or design rules that provide a sustainable design framework. The most important aspect in Green Chemistry or green chemistry is the design concept because design is a statement or intention regarding planning and systematic conception (Anastas & Eghbali, 2009).

Good education will produce individuals who have the knowledge and skills because education is the key to economic sustainability in the 21st century. These four skills are known as 4C, namely Critical Thinking, Communication, Collaboration and Creativity and Innovation. creativity and innovation) (Trilling & Fadel, 2009). Creativity can be formed through students' creative thinking skills (Cheung & Wong, 2011). Creative thinking is also defined as the process of gathering information to generate new understandings, ideas or concepts (Srikoon et al., 2018).

Several studies have found that students' creative thinking abilities are still low, such as research by (Sugiyanto et al, 2018) which states that the initial profile of students' creative thinking abilities in biology learning is low, so students' creative thinking abilities must be taken seriously. According to (Supardi, 2015), the low ability of students' creative thinking is due to the fact that current formal education only emphasizes the cognitive domain. It can be seen from the learning process at school where activities that require divergent thinking or creative thinking are rarely carried out. As a result, students are not stimulated to think, act, and behave creatively. This opinion is also in accordance with what was found by (Lukman Nulhakim, 2020) which states that the learning process in class, including science learning, is still teacher-centered, so it does not provide opportunities for students to develop creative thinking skills.

▪ METHOD

This research is a qualitative descriptive study. Qualitative descriptive research is an approach or search to explore and understand a central phenomenon (Creswell, 2009). The purpose of using qualitative methods is to reveal a phenomenon as it is or a detailed report from the views of participants. Qualitative descriptive research was used in this study with the aim of obtaining information about learning activities and profiles of students' creative thinking abilities at SMA N 2 Cibinong.

The population is all data that concerns us in a scope and time that we determine (Margono, 2014) The population of this study is class XII students at SMA N 2 Cibinong. The sample of this study were 36 students of class XII IPA 7 SMA N 2 Cibinong consisting of 15 male students and 21 female students. The sample is part of the number and characteristics possessed by the population (Sugiyono, 2012). The sampling technique in this study was carried out by means of purposive sampling. Purposive sampling technique is a sampling technique with certain considerations (Sugiyono, 2012). In this study, sample selection was assisted by a chemistry teacher who teaches at SMA N 2 Cibinong with consideration of cognitive values and learning schedules.

The research was conducted by observing learning activities on the topic of fire-resistant bamboo using green chemistry-oriented ionic liquids that occurred in class XII IPA 7 SMA N 2 Cibinong. The research design is DDR (design didactical research) with the research stages in the form of (1) situation analysis before learning to design a fire-resistant bamboo learning design using onic fluids orientated by geen chemistry which includes learning objectives, didactic situations, predictions of student responses, and teacher anticipation of student response. (2) analysis of the didactic situation during learning in the form of implementation of learning designs (observation, teacher reflection with observers, and making transcripts). Implementation was carried out during two learning meetings (3) analysis after learning, namely conducting an analysis of learning transcripts (Suryadi.2013).

In this study, instruments were used in the form of interview sheets (validated by two validator lecturers and one teacher), observation sheets, documentation (photos and video-audio during implementation activities). In qualitative research methods, the researcher himself is a data collection tool and cannot be represented. This means that researchers are directly involved with participants or participants (Raco, 2018). The data from the observation sheet is in the form of learning transcripts which contain teacher-

student conversations, and student-student conversations. Learning transcripts will be equipped with video-audio recordings during implementation or learning activities. Learning transcripts will be analyzed using Transcript Based Lesson Analysis (TBLA) or transcript-based lesson analysis. TBLA aims to investigate the characteristics of a lesson (Arani, 2017). The ability to think creatively is identified using indicators of creative thinking according to Munandar (1992), namely fluency, flexibility, originality, elaboration, and evaluation. Learning transcripts that contain teacher-student and student-student conversations or dialogues will be coded according to indicators of creative thinking according to Munandar (1992). The results will show students' creative thinking abilities during learning implementation activities through the number and percentage of occurrence of creative thinking indicators. To ensure that the data obtained is valid, re-checking and triangulation of sources are carried out, namely comparing and re-examining the level of confidence in information obtained through different times and tools in qualitative research (Moleong, 2004).

▪ RESULT AND DISSCUSSION

The learning design of fire-resistant bamboo using ionic liquids orienting green chemistry is a learning design that integrates the topic of fire-resistant bamboo with chemical and polymer bonding materials. The chemical bonds discussed in this topic are covalent bonds formed between cellulose and ionic liquids. This is evident from NMR studies, namely the carbon signal (C-1) in the glucose unit disappears, so that the ionic liquid forms a covalent bond between the C-1 carbon of the glucose unit and C-2 of the imidazolium core (Heinze, 2008). Bamboo treated with ionic liquids will dehydrate the bamboo and reduce % elemental H and % elemental O. Meanwhile, % element C has increased which is indicated by increased production of charcoal residue (Miyafuji, 2015). Furthermore, the relevance of the topic with polymeric materials is on the main components that make up bamboo. The main components of bamboo, which are cellulose, hemicellulose and lignin, are natural polymers (Liu, 2018).

The learning design of fire-resistant bamboo uses a problem-based learning model. Implementation or learning activities carried out in two meetings. At the first meeting the learning activities consisted of three activities, namely preliminary activities, core activities, and closing activities. Preliminary activities in the form of attendance and introduction to the topic of fire-resistant bamboo using ionic liquids. While the core activities follow the problem based learning syntax, namely problem orientation, organizing students to learn, and guiding individual and group investigations. Finally, in the closing activity, a presentation is made. The analysis was carried out in all three parts of the learning activities. The results of the analysis aim to reveal the profile of students' creative thinking abilities. students' creative thinking skills that appear the most during learning activities at the first meeting of the first indicator are fluency with a percentage of 60.1%. While the second indicator, namely flexibility, appears as much as 9.7%, the third indicator, namely originality, appears as much as 3.2%, the fourth indicator, namely elaboration, appears as much as 13%, and the fifth indicator, namely evaluation, appears as much as 14%. The number of occurrences of students' creative thinking indicators during learning activities, if sorted from the most appearing to the least appearing, is the first indicator (fluency) 451 times, then the fifth indicator (evaluation) 105 times, the fourth indicator (elaboration) 98 times. times, the

second indicator (flexibility) 73 times, and the third indicator (originality) 24 times. The following is a diagram of the percentage of creative thinking indicators appearing at the first meeting.

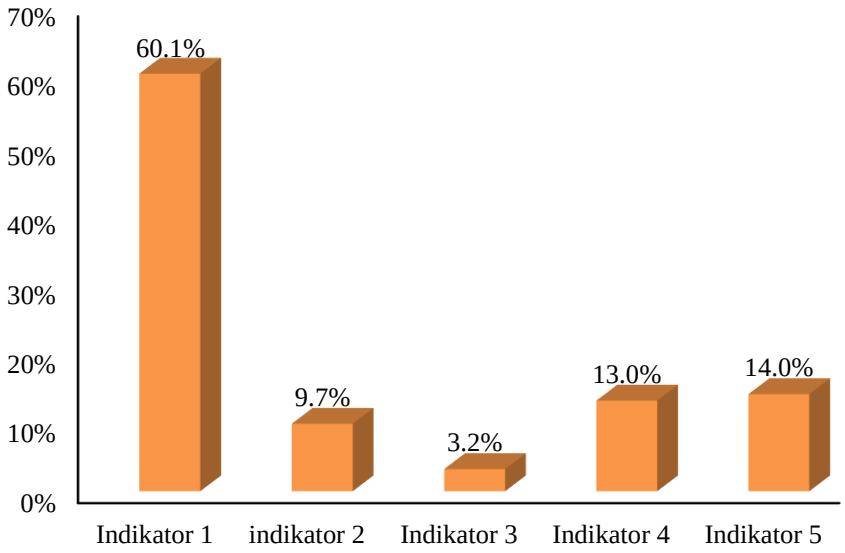

Figure 1. Students' creative thinking skills for 1st meeting

Preliminary activities begin with the teacher checking student attendance and introducing the topic of fire-resistant bamboo using ionic liquids through a number of questions given by the teacher. The topic of fire-resistant bamboo using ionic liquids is new to students. This learning topic integrates material on chemical bonds (covalent bonds) and polymer materials. The chemical bond material is found in the bond formed between cellulose (glucose) and ionic liquids and the polymer material in this topic is found in the main components of bamboo (cellulose, hemicellulose and lignin) which are a group of natural polymers.

The emergence of fluency creative thinking indicators in the preliminary activities occurred 19 times. Preliminary activities in the form of giving a few questions raises creative thinking indicator 1 because the students who answer the teacher's questions belong to indicator 1. The questions given are related to the meaning of bamboo, the advantages of bamboo, and examples of products made from bamboo. In the preliminary activity, there was also the appearance of indicator 4 2 times. The emergence of indicator 4 (elaboration) is related to students who add their friends' answers when the teacher gives questions related to learning topics. However, indicator 2, indicator 3, and indicator 5 did not appear because the teacher's questions in the preliminary activity only asked students to name and explain according to the teacher's goal of introducing the topic of fire-resistant bamboo using ionic liquids.

Furthermore, in the core activities, starting with problem orientation. The problem given by the teacher is how to deal with flammable bamboo. after that, students were divided into six groups and given LKPD and reading materials. The group consists of two male students and four female students. The formation of groups is carried out with the aim of students being able to discuss in solving a given problem. As a result, group

2 became the group with the most occurrences of indicator 1, namely 93 times, and the first indicator appearing the least in group one, namely 42 times. Group 1 is the group with the fewest indicators of first creative thinking. In group 1, the appearance of the first indicator in group 1 occurred when students asked about "what is the hypothesis?" included in the ask a question sub-indicator. Furthermore, the first indicator continued to appear until the end of the discussion activity when students gave answers on how to overcome the weaknesses of flammable bamboo which was included in the first sub-indicator, answered questions and conveyed ideas smoothly. The small appearance of indicator 1 (Fluency) in group 1 was caused by the conditions that occurred. Students in group 1 are less active in discussing in answering questions in LKPD. Group 1 students read more to answer the questions in the LKPD and if they are unsure about the answer, then the student reveals it to another friend. To overcome this, the teacher often approaches group one and asks them to discuss to find the answer. In contrast to group one which is the group with the least occurrence of the first indicator, group 2 is the group with the most occurrence of the first indicator. The initial appearance of the first indicator occurred when students discussed the formulation of the problem. Events that occur are students trying to formulate a problem. This is included in the sub-indicator of answering questions and expressing ideas fluently. Discussion activities in group 2 make the first indicator often appear due to active group discussion activities. Group 2 students ask each other questions, provide answers and present their ideas during discussion activities so that the appearance of indicator 1 occurs a lot in this group.

The next indicator that appears a lot in core activities is the fifth indicator (evaluation). The fifth indicator appeared 105 times with the most incidents occurring in group 4 as many as 26 times. The beginning of the emergence of the fifth indicator in group 4 occurred when students gave opinions regarding the formulation of the problem. The situation that occurred, one of the students gave his opinion regarding the formulation of the problem. This includes expressing one's own opinion about something. Furthermore, the fourth indicator (elaboration) appears 98 times with the initial appearance when students discuss making problem formulations. One of the students added to the formulation of the problem posed by a groupmate. This is included in the fourth sub-indicator in the form of developing and enriching other people's ideas. This indicator generally appears when students add to their friends' answers, which means students complement or enrich their friends' ideas.

The second indicator, namely flexibility, also appears 73 times in the core activities. The second indicator appears for the first time in the introduction activity on index 8 with the situation that occurs when students provide information based on pictures of bamboo structures displayed by the teacher. This includes providing image interpretation. The appearance of indicator 2 is not as much as indicator 1 because the topic or learning activity does not require students to get information based on the presentation of the picture and also this indicator 2 is related if there are other students who disagree. However, in implementation, it was found that there were two or three students who led the discussion and other students often agreed with the ideas conveyed by their friends. The appearance of the second indicator was the most common in group 3, namely 24 times, with the initial appearance occurring at index 94 when students formulated problems or made hypotheses. Group 3 students are more active and often contradict their friends' ideas because they have different thoughts or ideas. Finally, the

indicator that appears the least at this first meeting is the 3rd indicator, namely originality with a total of 24 appearances. Indicator 3 (originality) appears when students discuss making problem formulations. This third indicator relates to unique ideas, and different from others.

In the core activities, the teacher only acts as a facilitator and guides if students ask. This is what causes the emergence of indicator 1 mostly due to active students giving answers, asking questions and expressing their ideas during discussion activities. Meanwhile, the appearance of indicator 2 which appeared a little in the core activities was caused by students who tended to agree with indicator 2, in which indicator 3 appeared at least due to the provision of reading material by the teacher at the beginning of the core activities. Providing reading material to students causes new and unique ideas or ideas from students not to appear during student discussions. Students get answers from reading material and focus on the reading material. Furthermore, in the closing activity section, there is no emergence of creative thinking indicators because in this section the presentation of the problem formulation and hypotheses that have been carried out is carried out. The teacher arranges the order of presentations and when students give presentations, there is no discussion or question and answer and input from other groups.

The profile of creative thinking skills can also be seen in the second learning meeting (fig.2). The percentage of the emergence of creative thinking indicators at the second meeting of the implementation of this fire-resistant bamboo learning design, namely the first indicator (fluency) appeared as much as 62.1%, the second indicator (flexible) appeared as much as 12.3%, the third indicator namely originality appeared as much as 0.1 %, the fourth indicator (elaboration) appears as much as 13.8%, and indicator 5, namely evaluation, appears as much as 11.6%. At this second meeting, students continued the discussion activities from the first meeting and made presentations. Discussion activities carried out to develop and present data. In the initial activity part, only the teacher's activity occurred giving instructions to sit in groups and continue discussion activities so that student dialogue did not appear which is one of the indicators of creative thinking.

In the main activity which is a discussion activity, it can be seen that the most occurrence of indicator 1 is in the first group with 97 incidents. The initial appearance of the first indicator in group 1 occurred during a discussion activity when one of the students asked "why is bamboo flammable?". Questions that arise from these students are included in one of the first sub-indicators, namely asking. Furthermore, the first indicator continues to appear until the end of the discussion activity when students discuss in making conclusions which are included in one of the first sub-indicators in the form of owning and fluently expressing their ideas. the appearance of indicator 1 which occurs a lot compared to other indicators is related to the discussion activities carried out by students. Similar to the first meeting, class XII IPA 7 students participated in learning activities very well and actively. Students fluently express ideas to answer the questions given. The character of students like this certainly has a big influence on the appearance of indicator 1. Furthermore, the fourth indicator (elaboration) appears the most. The fourth indicator appeared the most in group 6, namely 27 times, with the initial appearance in a discussion activity situation when a student added to his friend's answers regarding the main components of bamboo. This is

included in the sub indicator of enriching other people's ideas. Students during discussion activities complement each other in finding information about the problems being solved.

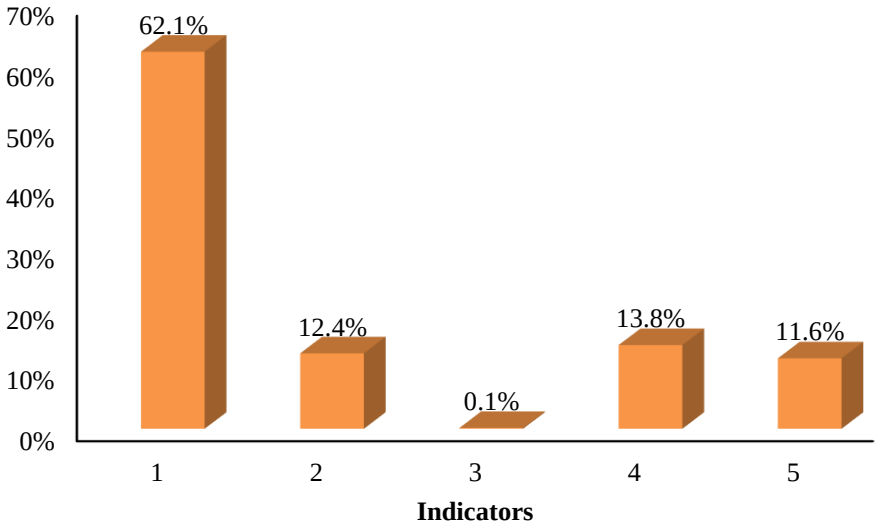

Figure 2. Students' creative thinking skills for 2nd meeting

The second indicator (flexibility) is also seen in the second learning activity. The beginning of the emergence of the second (flexible) indicator in group 1 was when students discussed the reasons bamboo was flammable. One of the students gave a different answer from that proposed by his friend. This is included in one of the second sub-indicators, namely in the form of talking about something, having a stance that is contrary to the group. The second indicator continued to emerge during the discussion activities. As discussed earlier, students who share their ideas during discussion activities cause students to sometimes clash with their group members because of different ideas. However, this difference is resolved by students by re-reading the source of information and showing the reasons for their ideas to other friends. Furthermore, regarding the appearance of the fifth indicator, namely evaluation. The fifth indicator (evaluation) first occurred in group 1. The situation that occurred was when one of the students gave his opinion about why bamboo is flammable. This is included in the fifth sub-indicator in the form of expressing one's own opinion about something. Finally, the indicator that appears the least is indicator 3 or originality. Appearance of indicator 3 only occurs in group 2 of the main activity section with 1 occurrence. The emergence of indicator 3 in group 2 occurred when students discussed the bonds formed between the bamboo component (cellulose) and ionic liquids. One of the students said to look at the elements to find out the bonds formed. This is included in one of the third sub-indicators, namely thinking about things that other people don't think about. Indicator 3 which only appears once is because students are looking for answers to questions in the LKPD by reading the material provided by the teacher and looking for answers on the internet. So that new and unique expressions, things that other people don't think of, and other ways of thinking don't appear to students during discussion activities.

▪ CONCLUSION

The profile of students' creative thinking abilities that emerged during the implementation of the fire-retardant bamboo learning design at the first meeting was indicator 1 (thinking fluently) 451 times, the second indicator (flexibility) 73 times, the third indicator (originality) 24 times, the third indicator four (elaboration) 98 times, and the fifth indicator (evaluation) 105 times. While in the second meeting, the first indicator (fluency) appeared 455 times, the second indicator (flexibility) 91 times, the third indicator (originality) appeared 1 time, the fourth indicator (elaboration) appeared 101 times and indicator 5 (evaluation) appeared 101 times. 85 times. Indicator 3 is the indicator that appears the least which is caused by students looking for answers in the material provided and on the internet. This causes the emergence of a unique and new student dialogue from the student. In addition, at least the third indicator appeared at the first meeting and the second meeting was also caused by the provision of reading material by the teacher. In contrast to the third indicator, the first indicator (fluency) is the indicator that appears the most during the implementation of the learning design.

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