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Research Article:

Design of a Teaching-Learning Sequence and Its Effect on Self-Efficacy and Perceptions of Prospective Chemistry Teacher Students: An Educational Reconstruction Study of Fire-Retardant Bamboo

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ABSTRACT

This research was conducted to reconstruct the sustainability-oriented learning stages' design on fire-retardant bamboo and its effect on self-efficacy and perceptions of prospective chemistry teacher students. This study uses mix method with Exploratory Sequential Design, which is guided by the Model of Educational Reconstruction (MER) with the following stages: (1) content structure analysis, (2) research on students' pre-conceptions, and (3) learning design development. The instruments used were text analysis sheets, interview guidelines, validation sheets for the design of the learning stages, and questionnaires on student self-efficacy and perceptions. The topic used to develop the learning stages is the concept of ionic liquids as fire-retardant agents. The research data are scientific conceptions related to learning issues and chemical ideas. In addition, students' pre-conceptions regarding learning topics were obtained, followed by results validating the design of learning stages as well as the ability of students' perceptions and self-efficacy. The scientist's conception was analysed using the content qualitative analysis method, resulting in a concept map. The result of students' pre-conception on fire-retardant bamboo interview showed that the topic was new to the students. The percentage of students' self-efficacy abilities increased to 88.9%, which is in the excellent category. The students' perceptual abilities rate increased to 92.8%, which is in the agreed category. Thus, the design of sustainability-oriented learning stages on fire-retardant bamboo can increase the self-efficacy and perceptions of prospective chemistry teacher students. The design of the learning stages can help prospective teacher students integrate chemical concepts with technological engineering in learning. Using sustainable materials in the learning stages can foster sustainability literacy in students and support the creation of sustainability-oriented education in the higher education environment

Keywords: Fire-retardant bamboo, ionic liquid, sustainable material, teaching learning sequences

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INTRODUCTION

Currently, the increase in human population has an impact on the high exploitation of natural resources. This excessive exploitation of natural resources causes other problems, such as environmental, social, and economic problems (Purba et al., 2020). Implementing sustainable development goals is one of the steps to overcome this problem (Kibert 2003). Sustainable development goals can be implemented using sustainable materials as a substitute for natural resources whose availability is low and difficult to renew (Krautkraemer, 2005). Materials included in sustainable materials can reduce the use of natural resources that are difficult to continue and have a low ecological impact. In addition, sustainable materials do not risk human health and the environment, are easy to produce, and are abundantly available in nature (Xu & Shi, 2018). One of the materials that meet sustainable characteristics is bamboo.

Bamboo is a highly adaptive plant because it adapts easily to different biodiversity, climate, and soil conditions (Suriani, 2017). Bamboo has perennial properties and a faster growth rate because it can be harvested every 3 to 5 years (Dasappa & Bharti, 2016). Bamboo is also a very versatile plant because it can be used for various things, such as construction materials, furniture, and paper (Akinlabi et al., 2017). These facts show that bamboo is a material that has a potential to be used as a sustainable material in Indonesia; therefore, its use must be maximised. However, bamboo is flammable, limiting its application, especially in construction (Alongi & Malucelli, 2015; Horrocks, 2011). Bamboo also has electrostatic properties, resulting in an explosion risk (Roessler & Schottenberger, 2014)

Utilising ionic liquids is one way to maximise the usage of bamboo as a sustainable material. Ionic liquids are materials that contain only ionic species (cations and anions) and no neutral molecules. Ionic liquids also have a comparatively low melting point at temperatures ranging from 100 to 150° making them liquid at room temperature (Hagiwara & Ito, 2000). Ionic liquids have a wide liquid range and are non-flammable and non-volatile. According to Miyafuji and Fujiwara (2018), ionic liquids can be used as fire retardant substances in wood. Bamboo is a cellulose-bearing plant, and research has demonstrated that ionic liquids can be employed as fire retardants in materials containing cellulose fibers (Liu et al., 2017). These studies provide the foundation for the use of ionic liquids as fire retardants in bamboo. However, no research has been conducted to integrate this topic into learning, despite the fact that it can assist students develop sustainable behaviours. Sustainable development must be properly integrated throughout the higher education curriculum so that students from all subjects are prepared with the knowledge and skills required to promote a sustainable society (Rowe, 2002).

Understanding self-efficacy and individual perspectives is required to create change and growth in sustainability practices (Gifford, 2011). Self-efficacy is an individual's self-confidence or belief in his capacity to do various things, ranging from performing duties to organising and producing something to reach specified goals (Bandura, 2007). The notion of self-efficacy has garnered increasing attention in educational research over the last few decades. Several studies have been conducted to investigate the effect of students' self-efficacy on motivation and learning (Linnenbrink & Pintrich, 2003; Schunk, 2003; Zimmerman et al., 1992), and the results show that self-efficacy influences motivation and cognition by influencing learners' interest, task persistence, goals they set, and choices they make. In addition to self-efficacy, students' perceptions of chemistry also influence their attitude toward sustainability. Studies have reported that learners' perceptions of difficulties regarding the relevance of chemistry to everyday life are correlated with their success in learning (Zusho et al., 2003; Kar et al., 2014). When studying chemistry, students require a broad and practical science education. To provide a relevant and comprehensive science education, educators must successfully convey chemistry content knowledge while also creating a learning environment that fosters students' problem-solving abilities and assists them in improving their perception of the relationship between chemistry, technology, and society (Marks & Eilks, 2009; Hofstein et al., 2011).

Sustainability-oriented learning is one method of incorporating sustainable development into higher education curriculum, particularly the chemistry education curriculum. The topic of fire-retardant bamboo can be used in the chemistry education curriculum to implement sustainability-oriented learning. To effect change and grow sustainability attitudes, applied sustainability-oriented learning must pay attention to students' self-efficacy abilities and self-perceptions. As a result, developing a learning stage design (Teaching Learning Sequences [TLS]) that includes activities aimed at improving prospective chemistry teacher students' learning about sustainability is required. TLS development focuses on designing and evaluating curricular products for small-to-medium-scale activities (Méheut & Psillos, 2004). This activity is organised into modules or programs (Méheut & Psillos, 2004).

Sustainability-oriented learning is one way to integrate sustainable development into the higher education curriculum, especially the chemistry education curriculum. The topic of fire-retardant bamboo can be used in the chemistry education curriculum to implement sustainability-oriented learning. Sustainability-oriented learning that is applied needs to pay attention to the students' self-efficacy abilities and their self-perceptions to create change and growth of sustainability attitudes. Therefore, developing a learning stage design (TLS) that includes activities that aim to improve prospective chemistry teacher students' learning about sustainability is necessary. TLS development focuses on designing and evaluating curricular products covering small to medium-scale activities (Méheut & Psillos, 2004). This activity is structured based on several modules or programs (Méheut & Psillos, 2004). The development of TLS is carried out to develop students' learning process on specific topics (Méheut & Psillos, 2004). TLS development is carried out to enhance students' learning processes on specific topics (Méheut & Psillos, 2004).

This study was carried out in order to reconstruct the design of the sustainability-oriented learning stages on fire-retardant bamboo. Furthermore, the purpose of this study is to determine the impact of developing the learning stages on the self-efficacy and perceptions of prospective chemistry teacher students. Based on these objectives, the following research questions will be examined in this study:

1. What is the scientist's take on the topic of fire-resistant bamboo in terms of sustainability?
2. What are prospective chemistry teacher students' perceptions of fire-resistant bamboo related to the concept of sustainability?
3. What are the learning stages designed for the sustainability-oriented fire-resistant bamboo topic lectures?
4. How is the self-efficacy ability of prospective chemistry teacher students related to refractory bamboo lectures before and after learning?
5. What are prospective chemistry teacher students' perceptions of fire-resistant bamboo lectures before and after learning?

LITERATURE REVIEW

Teaching Learning Sequences

Teaching Learning Sequences (TLS) is an intervention research activity and product, such as a curriculum unit package that includes well-researched teaching and learning activities that are empirically adapted to students' reasoning. Furthermore, the design of learning stages can be in the form of teaching guidelines that include expected and student reactions (Testa & Monroy, 2016). The method of the learning stages consists of several steps (Leach & Scott, 2002):

1. The stage that identifies the school science knowledge to be taught,
2. The stage that considers how this field of science is conceptualised in students' daily lives,
3. The stage that identifies learning demands by assessing the nature of each difference between the identification and consideration stages.

The contents of the learning stages include teaching and learning activities that have been well-researched and empirically adapted to the needs of students (Zuza et al., 2020).

Designing learning stages is a complex activity that must consider all three aspects of the didactic triangle: content, teacher, and students (Muñoz-Campos et al., 2020). Among these three components, subject-specific didactics become the focus for analysing subject content to develop an effective presentation and arrangement of content for teaching and learning (Ruthven, 2012). The educational context of teaching and learning activities also needs to be considered. Therefore, the preparation of learning stages must assist teachers in conveying students' competencies. In addition, the practice of learning stages needs to pay attention to the teacher's treatment so that students can think, communicate, do and feel what they are learning (Muñoz-Campos et al., 2020).

Designing the stages of learning requires a theoretical framework. The model of educational reconstruction (MER) can be chosen as a theoretical framework to integrate science and technology from the content knowledge point of view. MER is a suitable framework for identifying key ideas in science and natural phenomena utilised by technological devices or processes. There are three interlocking components in MER:

1. The first component refers to the clarification/identification of scientific ideas on certain content.
2. The second component refers to the analysis of students' perspectives.
3. The third component refers to the design of teaching materials and activities.

Several studies have been conducted to develop learning stages in chemistry education using the MER framework. Nursa'adah et al. (2020) succeeded in describing learning sequences on the concept of metallic bonding through the MER framework. The learning design developed starts with the student's closest context then investigates the context to strengthen the studied content. Another study has successfully created an inquiry-based learning stage design on nanoscience and nanotechnology (Stavrou et al., 2018). The design of the learning stages has been disseminated to teachers and the professional learning community. The design results of the learning stages are adaptive and flexible. It can also be adjusted according to the context.

Sustainability

Learning stages were developed to realise sustainability-oriented learning in the chemistry education curriculum. Sustainability is the knowledge, skills and mindset that enable individuals to become highly committed to building a sustainable future and assist in making informed and effective decisions for sustainable development goals (Zwickle et al., 2014). Sustainability literacy is an approach to develop students' awareness of sustainability issues and to build related skills such as communication and problem-solving (Murray, 2012). Based on the concept of sustainable development, the indicators of sustainable development will not be separated from economic, ecological/environmental, social, political, and cultural aspects. There are four areas of development that need to have sustainability capabilities, including: (1) conceptual awareness of sustainability issues in the real world; (2) personal identity and values that are aligned with the achievement of sustainability; (3) competence in skills that can contribute to achieving sustainability; and (4) belief in the ability to contribute to achieving sustainability (Diamond & Irwin, 2013). Research conducted by Chen et al. (2020) combines green chemistry education with other disciplines to promote sustainability education. This research shows that applied sustainability-oriented learning can deepen students' understanding of the relationship between the natural environment and humans. The learning process also supports students' understanding of the synthesis and integration of intangible links between nature and human well-being.

Bamboo as a Sustainable Material

One way to apply sustainability learning is to use sustainable materials or materials to replace natural resources that are almost depleted, such as bamboo. Bamboo is a clumpy, segmented, rooted, hard plant that can grow to be 10 to 20 meters high. It is a highly adaptable plant with a rapid growth rate. Because agricultural water requirements are shallow (<2000 mm), bamboo can be grown in all soil types. It is relatively easy to cultivate and harvest, and it can be reused for 3 to 5 years (Dasappa & Bharti, 2016). As a result, bamboo is listed as a sustainable material. Bamboo is used in a variety of applications, including construction, primary material for furniture and musical instruments, as well as decorative material in textiles, paper, and handicrafts (Akinlabi et al., 2017). Previous research has also used bamboo as a construction material in sustainable architectural education (Xiang et al., 2021). Thus, this learning helps exploring sustainability's potential role in incorporating interdisciplinary knowledge, connecting specialised knowledge across different program levels, and motivating student learning. However, bamboo has the disadvantage of being flammable. Its combustible material and hollow rods can cause a loud explosion due to thermal expansion (Kaminski et al., 2016). The presence of cellulose is what gives bamboo its flammable properties. Bamboo has a high percentage of cellulose composition compared to hemicellulose and lignin; thus, cellulose has a significant impact on bamboo's properties, particularly in its flammability. In addition, the flammability of bamboo is caused by the innate nature of its components, which are 50% carbon, 6% hydrogen, and 44% oxygen. This chemical element quickly decomposes into combustible gas components when exposed to sufficient air and fire conditions.

Ionic Liquids as Fire-Retardant Substances

Ionic liquids can overcome the explosive properties of bamboo. Ionic liquids are materials that are composed solely of ionic species (organic cations and organic/inorganic anions), do not contain specific neutral molecules, and have a relatively low melting point (100°C –150°C) (Hagiwara & Ito, 2000). In contrast to molten salt, which has a high melting point, high viscosity, and is highly corrosive, ionic liquids are generally liquid at room temperature, have a low density, and are non-corrosive (Toma et al., 2000). The cation system in ionic liquids is generally an organic cation with bulk properties. The anionic systems in ionic liquids are usually chlorides, acetates and alkyl phosphates. One of the distinguishing characteristics of ionic liquids is their resistance to fire. Previous studies have shown that ionic liquids can work as fire retardants on wood (Miyafuji & Fujiwara, 2013), cellulose fibers (Liu et al., 2017), and epoxy resin (Xiao et al., 2017). Bamboo contains cellulose, and its main structure is similar to wood; therefore, ionic liquids can also be used as fire-retardant agents in bamboo.

METHODOLOGY

Research Design

This study employed mixed method. The term "mixed method" refers to research that employs both qualitative and quantitative methods (Wiersma & Jurs, 2009). The research design in this study is an exploratory sequential design. The framework of the MER developed by Duit et al. (2012) guided the mixed method research. The exploratory sequential design of the study, guided by MER, was divided into three interconnected stages. The stages are as follows:

1. Clarification and analysis of scientific contents and concepts: At this stage, a qualitative content analysis of fire-retardant bamboo is carried out to determine the related content that will be used in learning.
2. Research on students' pre-conceptions on fire-retardant bamboo: We conducted pre-conception research through interviews.

3. Design and assessment of the learning environment: This stage is divided into several sub-stages, including learning stage development, learning design implementation, and learning evaluation using efficacy and self-perception questionnaires.

Sample

This study included 15 chemistry education undergraduate students from a public university in Bandung, Indonesia. The purposive sampling method was used for sampling. The participants in this study were senior students who had completed introductory chemistry 1, basic chemistry 2, inorganic chemistry, and organic chemistry courses. The descriptive method was used to analyse the research data. As a result, 15 participants were sufficient to represent the research data.

Instrument

Scientists' conceptions of fire-resistant bamboo

The scientist's conception was obtained through a qualitative content analysis using 13 kinds of literature. The literature on ionic liquids as an anti-fire agent in bamboo as a sustainable material and chemical concepts related to the topic includes textbooks, monographs, review articles, and research articles.

Interviews

Interviews were conducted to explore students' preconceptions regarding ionic liquids as an anti-fire agent in bamboo. The interview guide was adapted from the Laherto (2012) interview format and contained questions related to topics such as "What is the underlying property of ionic liquids?"

The design of the developed learning stages

The validator validated the design of the developed learning stages using a validation sheet. The validation sheet asks the validator to provide suggestions for each planned didactic situation. The didactic conditions planned at the learning stage are arranged based on the taught content.

Self-efficacy Likert scale survey questionnaire

Self-efficacy was measured by a Likert scale survey questionnaire developed by Uzuntiryaki and Aydin (2009). It contains 20 questions that are divided into four categories. The first category is part of knowing the extent of student self-efficacy regarding the context of sustainable materials. The second category aims to determine students' self-efficacy regarding the context of bamboo content as a sustainable material. The third category is to determine students' self-efficacy regarding the concept of ionic liquids. In addition, the fourth category is part of knowing students' self-efficacy regarding students' views on chemistry in daily life. The reliability of the questionnaire was tested using the Cronbach Alpha test.

The self-perception Likert scale survey questionnaire

The self-perception Likert scale survey questionnaire developed by Zowada et al. (2020) was used in this research. It contains 13 statement items that are intended to determine students' perceptions of Ionic Liquids as Fire-retardant Substances in Bamboo before and after learning is implemented. The reliability of the questionnaire was tested using the Cronbach Alpha test.

Research Implementation

The research begins by conducting a qualitative analysis of the chemical content related to ionic liquid as a fire-retardant agent in bamboo to obtain a scientific conception. Afterward, participants were interviewed to discover their preconceptions associated with the research topic. Then, the learning stages are designed based on the obtained scientist's concept and the results of the participants' preconception interviews. Furthermore, the learning stages' design is implemented through an online learning. The design of the learning stages is arranged in Prezi-shaped media and implemented in online learning through Zoom meetings. Participants in the teaching were asked to complete self-efficacy and self-perception questionnaires before and after the learning.

Data Analysis Procedure

The data analysis techniques performed are as follows. The Qualitative Content Analysis (QCA) method (Mayring, 2014) and the type of literature analysis (Seuring et al., 2005) were used to examine scientists' perceptions of fire-retardant bamboo as a sustainable material. The QCA stages include material collection, descriptive analysis, category selection and material evaluation. Interview transcripts were analysed by categorising responses and converting them to percentages. Based on the assessment rubric, the answers to each question are assigned one of three scores: 0, 1 or 2. These findings were then descriptively and statistically analysed.

Profiles of students' self-efficacy abilities were analysed using a Likert scale questionnaire developed by Uzuntiryaki and Aydin (2009). Each question item was evaluated on a 5-point Likert scale: 1–Very bad; 2–Poor, 3–Medium, 4–Good, and 5–Very good. The Likert scale processing results were then calculated as a percentage score and analysed according to the categorization (Riduwan, 2011) as shown in Table 1.

Table 1. Interpretation of criteria for students' self-efficacy questionnaire score

Score (%)	Category
0–19.99	Very bad
20– 39.99	Bad
40–59.99	Moderate
60–79.99	Well
80–100	Very good

The profiles of students' self-perception abilities were analysed using a Likert scale questionnaire developed by Zowada et al. (2020). Each question item was measured using a 5-point Likert scale: 1–Very disagree; 2–Disagree; 3–Slightly agree and 4–Agree. The Likert scale processing results were then calculated as a percentage score and analysed according to the categorisation (Riduwan, 2011) as depicted in Table 2.

Table 2. Interpretation of criteria for students' perception questionnaire score

Score (%)	Category
0–24.99	Very disagree
25–49.99	Disagree
50–74.99	Slightly agree
75–79.99	Agree

RESULTS

The study was conducted based on the stages of research following the MER framework. The research results obtained at each stage are as follows.

Scientists' Conception of Fire-Retardant Bamboo as a Sustainable Material

The scientist's conception was obtained through a qualitative content analysis using 13 kinds of literature. The concepts obtained from the content analysis were converted into a concept map, as shown in Figure 1.

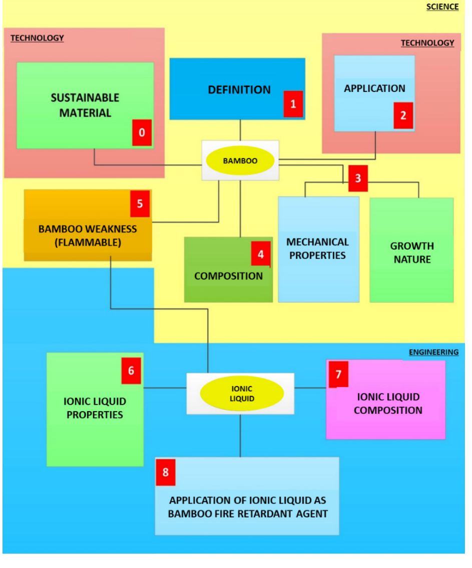

Figure 1. Concept map of scientists related to the topic of fire-retardant bamboo

The analysis results were grouped into science, technology and engineering categories. The contents in the science category are the definition of bamboo, its components, and its properties, which are marked in yellow. Furthermore, the content that is contained in the technology category is the application of using bamboo is marked in red. The engineering category are the properties of ionic liquids, components of ionic liquids, and the applications of ionic liquids to fire-retardant bamboo that is marked in blue. The number on the concept map indicates the order in which the content is delivered. The content will be explained step by step, as shown in Figure 2. Each stage corresponds to a concept map, relates to each other, and is linked to questions.

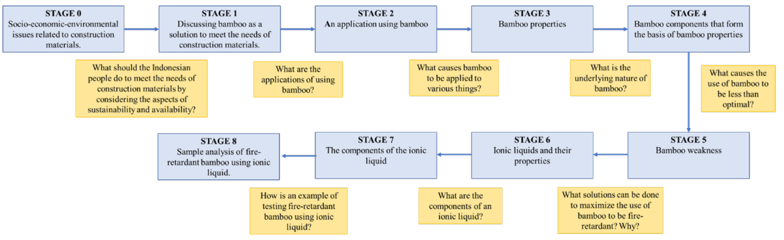

Figure 2. The sequence of content delivery based on the concept map

Pre-Conceptions of Prospective Chemistry Teacher Students on Fire-Retardant Bamboo as a Sustainable Material

Pre-conceptions of prospective chemistry teacher students were recognised through interviews. There are several categories of the interview results. The first category is students' knowledge of sustainable materials. The interview results showed that 53.3% of respondents have heard miniscule information about sustainable materials and only know less than three criteria of sustainable materials. It shows that most respondents are still unfamiliar with the term sustainable material and their requirements. The second category is the student's description of the context presented. This context is related to the content of bamboo as a sustainable material. Respondents' answers showed that 53.3% understand that bamboo is a sustainable material for the right reasons, and 60% only know one or two correct bamboo structures. However, 86.6% of respondents knew that the mechanical properties of bamboo depend on its constituent structure. It shows that most respondents already understand that bamboo is a sustainable material after observing several discourses and videos related to the criteria for sustainable material.

The third category is the questions about students' knowledge of ionic liquids. The interview results showed that 100% of the respondents knew ionic liquids. But 53.3% of respondents considered ionic liquids similar to molten salt. These results indicate that, generally, respondents still have misconceptions about ionic liquids. The fourth category is the questions about students' views on the interest and urgency of applying the concept of ionic liquids as fire-retardant substances to bamboo in chemistry learning. The interview results showed that 86.6% of respondents felt that the topics used are related to chemical content, and 100% of respondents agreed that the issue of ionic liquids is given to prospective chemistry teacher students to teach chemistry in high school. It means that the topic of ionic liquid as a fire-retardant substance in bamboo as a sustainable material is an interesting topic to be conducted at the university level. Furthermore, the interview results were considered in the making process of Teaching Learning Sequences.

The Design of the Learning Stages

The learning stages were designed based on the findings of pre-conception interviews on ionic liquids as fire-retardant substances in bamboo. The results of the preconception interviews showed that the participants were new to sustainable materials and had misconceptions about ionic liquids. The issues raised in the preconception interview are related to the content, then an appropriate learning situation are created. Preparing for this learning situation is also called the practice of a planned didactic situation. Planned didactic situations are learning stages that are arranged based on student learning obstacles in the following order: (1) sustainable materials; (2) bamboo definition and characteristics; (3) bamboo application; (4) bamboo mechanical properties; (5) bamboo composition; (6) bamboo is not fire resistant; (7) definition of ionic liquid; (8) differences between ionic liquids, liquid salts, and salt solutions; (9) ionic liquid properties and composition; and (10) ionic liquid as an anti-fire substance in bamboo.

Following that, predictions of student responses are arranged in accordance to the planned didactic situations to form hypothetical didactic design. An example of part of the hypothetical didactic design that have been compiled is shown in Table 3.

Table 3. The hypothetical didactic design

Content	Planned didactic situation	Anticipation
Bamboo composition	Students are asked to determine the main structure of a bamboo constituent based on the given chemical structure picture.	Educators present a table containing the main structure of a bamboo constituent according to each criterion.
	Students are asked to explain the relationship between bamboo structure and the mechanical properties of the bamboo.	Educators explain that its constituent structure influences the mechanical properties of bamboo.

The developed hypothetical didactic design had to be validated by the validator. Some important things to consider in the validation process are:

1. The suitability of the learning objectives to be achieved with the planned didactic situation.
2. The suitability of the expected didactic situation with predictions of student responses.
3. The suitability of predictions of student responses with educator anticipation.

Table 4 describes the validation results and suggestions for improvement. The validation results are used to improve the design of learning stages on fire-resistant bamboo.

Table 4. Validation results by the validator

No.	Content	Validator's suggestions
1	Sustainable materials	- Begin with an introduction in the form of a problem, and then move on to the topic of sustainable materials. - Inquire about the sustainability criteria for materials.
2	Bamboo	For the presented videos, it is better to present videos on the use of bamboo in general.
3	Definition of ionic liquid	Present pictures that can help students understand ionic liquids.
4	Ionic liquid as a fire-retardant agent in bamboo	Present an ionic liquid testing practicum video on bamboo to ensure that students understand the topic's conclusion.

The design of the learning stages was revised according to the suggestions given by the validator. Table 5 shows the design of the learning stages following the validator's suggestions. Furthermore, the learning stages' design is implemented through online learning.

Table 5. The design of the learning stages following the validator's suggestions

Content	Planned didactic situation / Problem	Anticipation/Educator activities
Socio-economic-environmental problems	Students are asked to explain the conditions of exploitation of natural resources based on pictures and determine how to deal with them.	Educators give examples of the exploitation of natural wood resources and their effects on social, economic, and environmental aspects. Educators direct that one of the solutions that can be done is to switch to sustainable materials.
Sustainable materials	Students are asked to explain the meaning of sustainable materials and determine the criteria.	Educators display answers which are sustainable material criteria and discuss them together. Educators display discourse about sustainable materials to increase students' understanding.
Bamboo	Based on the video, students are asked to determine the criteria for bamboo and explain whether bamboo is a sustainable material.	Educators give reaffirmation to students that bamboo is a sustainable material and provide explanations through tables.
Bamboo application	Students are asked to mention the application of bamboo.	Educators present pictures showing the application of bamboo and explain it.
Mechanical properties of bamboo	Students are asked to explain why bamboo can be applied to various things.	Educators explain that one of the factors that cause bamboo to be applied in various ways is its mechanical properties.

(Continue on next page)

Table 5 (continued)

Content	Planned didactic situation / Problem	Anticipation/Educator activities
Bamboo composition	Students are asked to determine the main structure of a bamboo constituent based on the given chemical structure picture.	Educators present a table containing the main structure of a bamboo constituent according to each criterion.
	Students are asked to explain the relationship between bamboo structure and the mechanical properties of bamboo.	Educators explain that its constituent structure influences the mechanical properties of bamboo.
Bamboo is not fire-resistant	Students are asked to explain the causes of flammable bamboo through pictures and find solutions to the problems.	Educators present discourse about the composition of bamboo, which causes bamboo to have explosive properties.
Definition of ionic liquid	Students are asked to provide feedback about ionic liquids	Educators display pictures of the structures that make up ionic liquids and explain the definition of ionic liquids based on the images shown.
Differences between ionic liquid, molten salt, and saline solution	Students are asked to determine ionic liquids, salt solutions, and molten salts based on pictures and explain the differences between the three.	Educators show the difference between molten salt, ionic liquid, and salt solution.
Properties of ionic liquids	Students are asked to explain what underlies the properties of ionic liquids based on the discourse.	Educators explain that ionic liquids' properties are determined based on the constituent cations and anions.
		Educators explain the types of anions and cations that can synthesize ionic liquids.
Ionic liquid as anti-fire substance in bamboo	Students are asked to conclude the results of the observations based on the given pictures.	Educators explain that ionic liquids can be applied as an anti-fire agent on wood.
	Students are asked to connect the results of the observation to a video practicum showing a test on ionic liquids as fire retardants on bamboo.	

Self-Efficacy Ability of Prospective Chemistry Teacher Students Before and After Learning

The Likert scale questionnaire used to determine students' self-efficacy abilities was divided into four parts: self-efficacy regarding the concept of sustainable materials, self-efficacy regarding the context related to bamboo content as a sustainable material, self-efficacy regarding the idea of ionic liquids, and self-efficacy regarding views of students in chemistry in everyday life. The average results of the total percentage of respondents' answers before and after learning are depicted in Table 6.

Table 6. The average result of the total percentage of students' self-efficacy before and after learning

Part	Before learning		After learning	
	Average total percentage (%)	Category	Average total percentage (%)	Category
1	57.00	Moderate	93.00	Very good
2	48.43	Moderate	89.71	Very good
3	36.60	Bad	86.40	Very good
4	53.16	Moderate	88.83	Very good
Mean	47.75	Moderate	88.95	Very good

The analysis results in Table 6 show an increase in students' self-efficacy abilities after applying the design of the learning stages. It can be seen from the rise in the average total percentage from 47.75% to 88.95%. It shows that the design of the learning stages affects students' self-efficacy abilities.

Perceptions of Prospective Chemistry Teacher Students Before and After Learning

The results of the Likert scale questionnaire analysis used to determine students' perceptions of learning are shown in Table 7.

Table 7. The average result of the total percentage of students' self-perceptions before and after learning

Statement	Average total percentage (%)	
	Before learning	After learning
1	45	100
2	52	95
3	52	97
4	45	100
5	57	100
6	58	98
7	93	97
8	90	98
9	63	100
10	65	93
11	62	38
12	68	93
13	72	97
Average	63. 23	92. 85
Category	Slightly Agree	Agree

Based on Table 7, it can be seen that almost every statement item regarding student perceptions has increased, except for item number 11. Although the percentage of statement item number 11 has decreased and the category has changed from slightly agree to disagree, it still shows positive results since the statement is negative. The analysis results in the table show a change in students' perceptions after applying the learning stages design. It can be seen from the increase in the average total percentage that goes from 63.23% to 92.85%. It shows that the design of the learning stages influences the change in students' perceptions of chemistry learning, especially on fire-retardant bamboo.

DISCUSSION

Scientists' Conception of the Topic of Fire-Retardant Bamboo as a Sustainable Material

The scientists' conception map on fire-retardant bamboo as a sustainable material was obtained through qualitative content analysis (Mayring, 2014), with the type of literature analysis (Seuring et al. 2005). Qualitative content analysis was performed using 13 kinds of literature. The collected literature sources come from textbooks, monographs, review articles and research articles. The literature obtained several scientific conceptions in the form of primary texts consisting of the definition of bamboo, the application of bamboo, the mechanical properties of bamboo, the composition of bamboo, the weakness of bamboo, the meaning of ionic liquids, the properties of ionic liquids, and the composition of ionic liquids. The primary text obtained from the descriptive analysis findings was used to develop questions for students' pre-conception interviews. In addition, primary texts were also used to compile teaching materials that students used during the trial of the learning stages design. The analysis results were grouped into science, technology, and engineering categories. Conceptions that are included in the scientific category are the understanding of bamboo, the components of bamboo, and the properties of bamboo. The conception that belongs to the technology category is the application of the use of bamboo. To add, the conceptions included in the engineering category are the content of ionic liquids, which consists of the properties of ionic liquids, components of ionic liquids, and the application of ionic liquids to refractory bamboo. The content categorisation was also grouped based on the existing system in Mahaffy et al.'s (2019) research.

Pre-conception of Prospective Chemistry Teacher Students on Fire-Retardant Bamboo as a Sustainable Material

Conception is a mental construction or representation of a situation (Brown et al., 2007). Pre-conception provides an overview of the initial concepts that students have before learning about sustainable materials, bamboo, ionic liquids, and ionic liquids as fire-retardant substances in bamboo. Pre-conception can be influenced by the learning that students have experienced. Therefore, the pre-conceptions possessed by each student are different and sometimes do not match the actual concept, so knowing the students' pre-conceptions is essential before designing the learning stages. One way to discover students' pre-conceptions is to conduct interviews (Niebert & Gropengiesser, 2013). This study used interviews by adapting the interview format from Laherto (2012) to explore students' pre-conceptions about the concept of fire-retardant bamboo.

The interview results showed that the topic of fire-retardant bamboo as a sustainable material is new to students. Students still have misconceptions about ionic liquids. Similar results were found in the study of Mudzakir et al. (2020), which states that students are unfamiliar with ionic liquids and their applications. It means that research uses renewable topics to provide students with an understanding of sustainable materials is needed. This topic can explain the potential application of techno-chemical activities in manipulating the structure of a material to produce different material properties. Therefore, prospective chemistry teacher students not only understand the sustainability aspect but can also understand the relationship between science and technology in the engineering of a product.

The Design of the Learning Stages

The design of the learning stages was developed based on several problems found during the pre-conception interview, such as misconceptions. After analysing these problems, a planned didactic situation was made in the form of learning stages that were arranged based on the results of students' learning barriers analysis. After that, predictions of the students' responses to the didactic situation were made. Educators' anticipation was also prepared if the planned didactic situation and the expected response prediction are inappropriate. Anticipation of educators could be in the form of indirect intervention through the application of scaffolding techniques (didactic actions) and/or encouragement for interaction between students (pedagogical activities) (Suryadi, 2010). The planned didactic situation design was still a hypothetical didactic design; therefore, validation was needed from expert lecturers in developing didactic designs, teaching materials, and content related to fire-retardant bamboo. Several things considered in the validation process were the suitability of the learning objectives with the planned didactic situation, the usefulness of the expected didactic situation with the predicted response of students, and the suitability of the predicted response of students with the anticipation of the educators.

Self-Efficacy Ability of Prospective Chemistry Teacher Students Before and After Learning

The analysis results in the table showed an increase in students' self-efficacy abilities after applying the design of the learning stages. It can be seen from the rise in the average total percentage from 47.75% to 88.95%. It shows that the design of the learning stages affects students' self-efficacy abilities. Self-efficacy is closely related to motivation and self-confidence in competencies and skills possessed. The increase in self-efficacy ability after the implementation of the learning stage design shows that the designed learning stages increase their motivation and self-confidence to realise the goals of sustainable development. It is consistent with several studies which state that self-efficacy affects motivation and cognition by influencing students' interest, task persistence, the goals they set, the choices they make, and the use of cognitive, meta-cognitive, and self-regulating strategies (Bouffard-Bouchard, 1990; Linnenbrink & Pintrich, 2003; Pintrich & De Groot, 1990; Schunk, 2003; Zimmerman et al., 1992). The topics used in designing the learning stages design are related to everyday life. Implementation of this learning stage design allows students to connect aspects of chemistry with their daily lives and characteristics of sustainable development. It is also one of the drivers who increase their self-efficacy after the implementation of the learning stage design is carried out (Rico et al., 2021).

Perceptions of Prospective Chemistry Teacher Students Before and After Learning

Perception is a process of interpreting, receiving, distinguishing, and giving meaning to the stimulus the senses receive to draw conclusions and interpret particular objects they observe (Asrori, 2009). The analysis results showed that students experienced an excellent chance after participating in the lesson. It can be seen from the increase in the average total percentage from 63.23% to 92.85%. This good perception changes occurs because implementing the design of the learning stages went well. The design of the applied learning stages can grow their motivation and interest in science that is related to sustainability development. It is so that they can successfully link aspects of science with sustainability development and everyday life. This success has changed their perception of the topic studied and its relation to sustainable development. It is in line with a study showing that students' perceptions of a learning topic are correlated with their success in learning (Zusho et al., 2003).

CONCLUSIONS

Based on the results of research and discussion, it can be concluded that the scientist's conception states that bamboo is a highly adaptive and versatile plant. The ionic liquid is a material that consists of ionic species, does not contain specific neutral molecules, has a relatively low melting point, and is refractory. The prospective chemistry teacher students' pre-conceptions show that students have limitations in understanding content related to learning topics. The design of the learning stages that have been made already contains learning outcomes. The average percentage of students' self-efficacy profile increased to 88.9% (excellent category). Similar to the aforementioned profile, the students' self-perception ability profile average rose to 92.8% (agree category). It shows that students' self-efficacy abilities and perceptions have changed very well after participating in learning. Chemistry learning using ionic liquids as refractory substances in bamboo topic can be one of the ways to implement sustainable development goals in the Asia Pacific region. It is because bamboo is a sustainable material that generally thrives in several countries in the Asia Pacific region.

LIMITATIONS

Based on the research results obtained, there are research limitations. The results of the implementation of the design of the learning stages only measure students' learning motivation, but do not measure the cognitive abilities of students. In addition, the performance of the learning stages design still uses conventional methods.

RECOMMENDATION

Based on the results of the research conducted, some recommendations for further study are as follows:

1. Based on the determination of learning barriers in related chemical content, further research may explore how to overcome the learning barriers identified in this study.
2. Future researchers can conduct research by applying the design of learning stages in lectures using the suggestions for improvement.
3. Future researchers can develop this research by using other types of bamboo located in the Asia Pacific region so that the use of bamboo as a sustainable material is not limited to certain types of bamboo in a country.

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