JKPK (JURNAL KIMIA DAN PENDIDIKAN KIMIA), Vol. 9, No.2, 2024 pp. 418-432
Chemistry Education Study Program, Universitas Sebelas Maret ISSN 2503-4146
https://jurnal.uns.ac.id/jkpk ISSN 2503-4154 (online)

PROJECT-BASED CHEMISTRY LEARNING ON THE TOPIC OF MAKING BIODEGRADABLE FILM FROM CORN COBS: A QUALITATIVE CONTENT ANALYSIS

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ARTICLE INFO

Keywords:
Chemistry Learning; Content Analysis; Teaching-Learning Sequence; Biodegradable Film; Corn Cob

Article History:
Received: 2024-07-11
Accepted: 2024-12-01
Published: 2024-12-25
doi:10.20961/jkpk.v9i3.90142

ABSTRACT

Plastic waste has brought us an enormous environmental challenge. One solution that could be done to solve the problem of plastic waste is to switch to ordinary plastic using biodegradable film. Corn cob is a type of lignocellulosic waste. And it could be used as biodegradable film material. This research aims to construct a Teaching-Learning Sequence (TLS) in film formation from corn cobs. The Teaching-Learning Sequences (TLS) that were designed can be made into lesson plans or learning materials with the Project-Based Learning (PjBL) model that fits with the "Projek Penguatan Profil Pelajar Pancasila (P5)" program in the current curriculum in Indonesia. This research is based on qualitative content analysis. It has four stages: collecting material, making a descriptive analysis, selecting categories, and evaluating. Data analysis and validation through experts were used. These validators included two experienced chemistry teachers and two chemistry education lecturers. Therefore, the validated Teaching-Learning Sequence (TLS) applies to learning activities. The discussion is split into four points: the first is the rate of plastic waste, the second is what corncobs consist of and their potential, the third is the process of creating biodegradable film, and the fourth point is the advantage of converting corncob waste to biodegradable film.

Corresponding Author: aasupri@upi.edu
How to cite: *N. Azizah, A. Supriatna, and T. Rahmawati, "Project-Based Chemistry Learning for High School Students on the Topic of Making Biodegradable Film from Corn Cobs: A Qualitative Content Analysis," Jurnal Kimia dan Pendidikan Kimia (JKPK)*, vol. 9, no. 3, pp. 418–432, 2024. [Online]. Available: http://dx.doi.org/10.20961/jkpk.v9i3.90142.

INTRODUCTION

Indonesia is the world's fourth-largest country by population. BPS noted Indonesia's current population was 279.79 million as of 2024, up 0.82% from 2023. Plastic waste is also growing because a large population produces high human consumption [1]. In 2023, there were around 26.1 million waste piles throughout the year, and 18.7% of them waste piles are plastic waste, according to data from the Ministry of Environment and Forestry (KLHK). In 2015, Indonesia ranked second as the largest contributor to marine plastic waste, negatively impacting the marine ecosystem. Roughly an estimated 620,000 plastic waste goes to ocean every year [2], [3], [4].

Today's plastics are mostly synthetic polymers derived from petroleum [5], [4]. The production process emits greenhouse gases and makes global warming worse. Plastics are polymers with a very large molecular size and are inert (do not react very quickly). Therefore, decomposing takes hundreds to thousands of years [3]. Plastic waste has a non-biodegradable nature that makes it difficult to degrade by nature in the soil [3], [6], [7]. As a result, plastic waste accumulates in oceans and landfills, which creates risks for human health and environmental damage and possibly affects marine life [7]. In light of increased environmental problems caused by plastic waste, environment-friendly alternative plastic materials that are biodegradable and made from inexpensive, renewable raw materials can reduce dependence on fossil fuels [9]. A solution to this plastic waste issue can be substituting conventional plastics with biodegradable plastics [8].

Bioplastics are natural polymers that can be processed like conventional plastics. Altogether, bioplastics decompose faster, require lower carbon output, and can be derived from differing natural sources. Some of these types of plastic can be properly broken down by microorganisms to produce water and carbon dioxide (CO_2) and then released into the environment [5], [11]. One of the types of biodegradable films that can be produced by using raw materials derived from agricultural products is bioplastic. These are polysaccharides, cellulose [12], [13], [14]. Corn is one of the agricultural products that can be used as a raw material for biodegradable film.

Indonesia is one of the top producers of beans, corn, rice, and cassava, essential crops for its people. Corn (*Zea Mays L.*) is one of the food crop commodities with a strategic role and value after rice [15]. In addition to corn production, corn cob waste will also increase [16]. This large quantity of waste corn cob can be a low-cost renewable product. Lignocellulosic waste, such as corn cob, contains cellulose, hemicellulose, and lignin [7], [8], [17]. Corn cobs, as a raw material, have high cellulose content and can be utilized as a more friendly and biodegradable alternative to plastic [18]. The use of corn cobs as the main raw material in the production of biodegradable films increases material innovation and product diversification opportunities that can be obtained from agricultural waste (corn, starch, fiber, sugar) as well as energy efficiency because it increases the value of waste and generates fewer emissions.

Therefore, in this research, the process of making biodegradable film from corn cob is adapted to the chemistry learning process at school using Project-Based Learning (PjBL). The Project-Based Learning (PjBL) approach is defined as an educational method for organizing and integrating theory with practice through real projects relevant to the student's life [19], [20]. Studying environmental issues through PjBL has an impact since it promotes knowledge and active student engagement, collaboration, and application [21]. Subsequent studies showed that applying the PjBL model in recycling plastic waste in the material of environmental pollution can improve students' learning outcomes [22].

Project-based learning (PjBL) is relevant to the current Indonesian curriculum program "Kurikulum Merdeka," known as "Projek Penguatan Profil Pelajar Pancasila (P5)" [6], [10]. Meanwhile, the P5 program is an attempt to develop students' character in the Pancasila Student Profile, which includes six competencies, namely: 1) Faith and piety to God Almighty and noble character; 2) Global diversity; 3) cooperation; 4) Independent; 5) Critical reasoning; and 6) Creative [23]. P5 focuses on authentic learning, creating opportunities for students to develop skills to face real-world challenges with creativity and innovation in mind. Project-based learning (PjBL) can make better the characters contained in Pancasila Student Profile [24] [25] [26] [27] [28]

This research uses concept maps for the students to understand the relations between each concept, which progresses to be developed in a teaching and learning sequence (TLS). TLS product and research [29]. TLS has also been proven to integrate research with school teaching and learning practices [30].

This research is a content-context analysis of learning by teaching a project to make biodegradable film from corn cobs that should be taught in secondary school chemistry learning. With that in mind, this research aims to use a conceptual map constructed into a teaching-learning sequence (TLS). Hopefully, this learning will provide opportunities to develop critical thinking, collaboration, and creativity through problem-solving in the local environment.

METHODS

1. Research Design

The research design used in this study is qualitative. Qualitative research was used to understand social, cultural, or behavioral phenomena in-depth. This study applies content analysis as its method. Qualitative content analysis was conducted to gain an in-depth understanding of the concepts, the context of the concepts, and the relationship between concepts derived from literature sources on the manufacture of biodegradable films from corn cobs by [31]. Content analysis is a technique for systematically describing the meaning of text data through a subjective interpretative process involving classification, systematic coding, and identification of themes or patterns. The qualitative content analysis in this study is based on [32]. Figure 1 shows the overall procedure of this research.

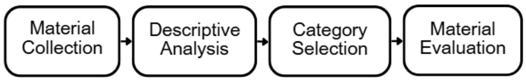

Figure 1. Stages of Qualitative Content Analysis

Material Collection

The research materials were derived from well-known databases, such as Google Scholar, Springer, and Elsevier, which were chosen for their diversity and the quality of their articles and journals. The literature was selected based on pre-set inclusion and exclusion criteria. The articles or journals must have been published in the last 10 years (2014-2024) and discuss the concept, context, process, and SDG aspects of biodegradable film production and use. On the other hand, through exclusion criteria, articles published beyond the time frame we set and articles that did not cover the topics sufficiently were excluded.

Literature was initially screened by reviewing titles and abstracts to evaluate the relevance of the literature to the research question. Then, a full-text screening was performed to assess the quality and categorize the literature based on themes consistent with the study aims. Collected literature was used to level the literature review.

This study conducted a descriptive analysis of 21 identified articles and journals that met due standards. These sources ranged from news articles to peer-reviewed journals. Data entries were arranged as evidenced by the articles in the news sources, coded as "A," and the related journal articles coded as "B." A qualitative analysis of the materials was conducted to identify key ideas on biodegradable plastics, referring to the production process using corn cobs and the drooping links of environmental concerns regulating daily living. This systematic procedure allowed for a thorough and structured investigation of the research topic.

2. Descriptive Analysis

A total of 21 articles and journals met the selection criteria in the database search for relevant literature. The reading materials referred to as literature were news articles and journal articles. The analysis was conducted from the descriptive side through the first stage of codification or coding, namely for articles originating from newswire coded A while journal articles were coded B, the analysis was conducted descriptively. Then, an in-depth analysis of each article was conducted to obtain the main concept of the biodegradable plastic concept, the process of making biodegradable plastic from corn cobs, and the environmental aspects that are close to life.

3. Category selection

The researcher will categorize those sub-themes into pedagogical and didactical themes after he analyzes and explores various kinds of literature in this part. The first codes were clustered in higher categories or themes. These categories were constructed around patterns in the data. Moreover, this category's selection is based on the nature of this project-based learning or for other purposes for preparing teaching modules based on the demands of the Merdeka curriculum and 21st-century learning.

4. Material evaluation

Literature and documentary evidence are reviewed at this phase until the analysis is categorized. Six months later, filtered content passed the review stage and was used as a basis for transmitting a systematic teaching-learning system (TLS). Figure 2 shows the overall picture.

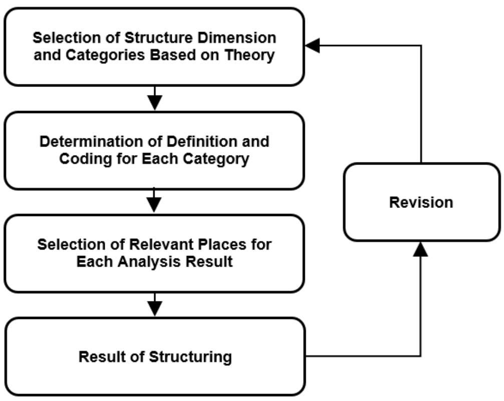

Figure 2. Structuring Process of Qualitative Content Analysis

The above Figure explains the structuring process of qualitative content analysis.

5. Expert Validation

The data collection tools were utilized in this study. Data on the product was collected from experts using a questionnaire method. This validation was performed by making a validation table and suggestions that could be useful in improving the teaching-learning sequences (TLS). Several expert validators performed validation consisting of a pedagogy expert and a concept chemistry expert, which included two chemistry teachers and two chemistry education lecturers. Experience in teaching and expertise in chemistry was considered for validating the validator.

RESULTS AND DISCUSSION

1. Material Collection

Data for this study were retrieved from Google Scholar, Springer, and Elsevier as trusted search engines until October 2023. Sources were selected according to predefined inclusion criteria. Applicable words used in the search include plastic and plastic waste; some keywords include biodegradable film, bioplastic, corn cob biopolymer, biodegradable film manufacturing, and aspects of SDG. A total of twenty-one relevant contents were extracted for further analysis.

The content was organized by type in the systematic participant section: (1) news articles (using codes A1 and A2) and (2) journal articles (using codes B1-B19). We outlined the data in tables and relations to enhance the clarity and efficiency of analysis and referencing. The contents of the selected data, such as title, year, author, and code, are summarized in Table 1.

Table 1. Material Collection

Title	Year	Author	Code
12 Juta Ton Sampah Plastik Menumpuk di RI, Terjadi Antrean Truk ke TPA	2024	Tia Dwitiani Komalasari [33]	A1
Sampah Plastik dan Perubahan Iklim, Seperti Apa?	2023	Ahmad Supardi [4]	A2
Pinniped entanglement in oceanic plastic pollution: A global review	2019	Emma M. Jepsen, P.J. Nico de Bruyn [34]	B1
The Potentials of Corn Waste Lignocellulosic Fibre as an Improved Reinforced Bioplastic Composites	2020	Ting Yen Chong, Ming Chiat Law, Yen San Chan [35]	B2
Elastic transparent lignocellulose bioplastics from corncob waste: positive effects of alkali treatment without bleaching process	2023	Passana Kongklieng, Takaomi Kobayashi, and Siriporn Taokaew [36]	B3
Physical, Mechanical, and Antibacterial Properties of Biodegradable Bioplastics from Polylactic Acid and Corncob Fibers with Added Nano Titanium Dioxide	2023	Moragote Buddhakala and Nopparat Buddhakala [37]	B4
Properties and Biodegradability of Films Based on Cellulose and Cellulose Nanocrystals from Corn Cob in Mixture with Chitosan	2022	Monserrat Escamilla-García, Mónica Citlali García-García, Jorge Gracida, Hilda María Hernández-Hernández, José Ángel Granados-Arvizu, Próspero Di Pierro and Carlos Regalado-González [38]	B5
The Effect of Carboxymethyl Cellulose (CMC) Addition on the Quality of Biodegradable Plastic from Corn Cob	2023	M. Bayu Ihsan, Ratnawulan [39]	B6

Antimicrobial Activity of Biodegradable Plastic Based on Corncob Waste Incorporated with Clove Essential Oil	2024	Ari Susanti, Dhea Kana Zafira [40]	B7
Lignocellulosic as sustainable resources for the production of bioplastics – a review	2017	Malin Brodina, María Vallejosb, Mihaela Tanase Opedala, María Cristina Areab, Gary Chinga-Carrascoa [41]	B8
Applications of Lignocellulosic Fibers and Lignin in Bioplastics: A Review	2019	Jianlei Yang, Yern Chee Ching, and Cheng Hock Chuah [42]	B9
Characterization and comparison of lignin derived from corn cob residues to better understand its potential applications	2019	Yu Wang, Wei Liu, Liguo Zhang, Qingxi Hou [43]	B10
Corncob Fractionations Toward Two Purposes: Furfural Production and Papermaking.	2023	Yufei Fan, Hairui Ji [44]	B11
Agricultural Waste Fibers Towards Sustainability and Advanced Utilization: A Review	2016	Rudi Dungani, Myrtha Karina, Subyakto, Sulaeman, Dede Hermawan and Hadiyane [45]	B12
Pembuatan Plastik Biodegradable dari Tongkol Jagung: Studi Kasus Desa Dawuhan Mangli, Kecamatan Sukowono, Jember, Indonesia	2019	Ari Susanti, Sartika D. Purwandari, Rendra S. Aji, Fanteri A. D. Suparno [46]	B13
Kajian Pembuatan Film Plastik Biodegradable Dari Ekstrak Bonggol Jagung	2021	Mukhlisien, Suhendrayatna, Mohd Montazeri, Hasnil Amar [47]	B14
Assessing Provisions and Requirements for the Sustainable Production of Plastics: Towards Achieving SDG 12 from the Consumers' Perspective	2022	Walter Leal Filho, Jelena Barbir, Pınar Gökçin Özuyar, Enrique Nunez, Jose Manuel Diaz-Sarachaga, Bertrand Guillaume, Rosley Anholon, Izabela Simon Rampasso, Julia Swart, Luis Velazquez and Theam Foo Ng [48]	B15
Degradation and Recycling of Films Based on Biodegradable Polymers: A Short Review	2019	Roberto Scaffaro, Andrea Maio, Fiorenza Sutera, Emmanuel Fortunato Gulino and Marco Morreale [49]	B16
Biodegradation of bioplastics in natural environments	2017	S. Mehdi Emadian, Turgut T. Onay, Burak Demirel [50]	B17
The potential of food waste as bioplastic material to promote environmental sustainability: A review	2020	M O Ramadhan and M N Handayani [51]	B18
Plant-based materials and transitioning to a circular economy	2019	Randal Shogren, Delilah Wood, William Orts, Gregory Glenn [52]	B19

2. Descriptive Analysis

The next step involves conducting a descriptive analysis of different types of literature gathered, including initial codes: bioplastic, biodegradable film, and corn cob. In addition, the literature collected and the preliminary codes were further analyzed to connect or group them to grow the problem topic into a greater theme or concept. The calculated final output of the analysis of results obtained can provide an explanation or description and summary of object steps or phenomena in detail, as shown in Table 2.

Table 2. Descriptive Analysis

Konten	Analysis
The phenomenon of Plastic Waste	In [33], it stated that Indonesia produced 12.87 million tons of plastic waste in 2023. Data from the National Waste Management Information System (SIPSN) of the Ministry of Environment and Forestry (KLHK) in 2023 shows the results of data input from 230 districts/cities throughout Indonesia, with the amount of national waste

	generation reaching 26.1 million tons. Of the total waste production, around 18.7% is plastic waste. Plastic waste is a serious threat that causes environmental damage, especially to water areas. According to the World Population Review, in 2021, plastic waste in Indonesian seas reached 56 thousand tons, and around 4.8-12.7 million metric tons of plastic enter the waters every year. This data shows Indonesia is the number five country contributing plastic waste to the ocean [4]. In the ocean, plastic debris can harm marine organisms in several ways: ingestion, accumulation on the seafloor, facilitating invasion of non-native species, and attachment of marine organisms. Accumulation of plastics on the seafloor can halt gas exchange and thus alter ecosystem function [31] [34]. Marine ecosystems and species are particularly vulnerable to plastic pollution, such as coral reefs that face the spread of disease through plastic pollution [4]. In addition, many plastics contain polychlorinated biphenyls (PCBs), which can increase the vulnerability of marine species. Plastic pollution occurs due to the widespread use of plastics, most of which are not biodegradable due to their high molecular weight and structure, which are too rigid for organisms to digest [34].
Biodegradable film as an alternative to plastic	The use of conventional plastics produced from petroleum is causing widespread environmental problems and marine pollution [35] because they are not biodegradable [35] [36] [37]. The high accumulation of plastics in the environment and the increasing biodegradation resistance have raised concerns about contamination [38]. The many environmental problems caused by plastics encourage the demand for environmentally friendly plastics with abundant and renewable raw materials, one of which is biodegradable plastic [39]. Biodegradable plastics are one of the environmentally friendly packaging solutions that can help alleviate the negative impact of petroleum-based plastics [40]. Biodegradability of plastics refers to deleting plastics into carbon dioxide and water without emitting toxic materials during composting [35]. Microorganisms can decompose biodegradable plastics faster than synthetic plastics [39]. Bioplastics or biodegradable films are produced from renewable resources such as lignocellulose. Lignocellulosic resources have the potential to replace plastic materials that can reduce widespread dependence on fossil fuels [41] [42]. Natural fibers are added as bioplastic fillers and accelerate the degradation process. They are environmentally friendly and offer other advantages, including recyclability, relatively higher specific strength, and stiffness [37].
Composition of Corn cobs and its potential as biodegradable film material	Corn (*Zea mays L.*) is one of the potential candidates for use as filler or plastic reinforcement. [35]. As corn production in Indonesia increases, corn waste will inevitably increase. [39]; the resulting by-products include corn cobs [35] [39] [40]. Corn cobs are one of the representative lignocellulosic wastes and are spread worldwide. [43]. Corn cobs contain three main components: cellulose, hemicellulose, and lignin. [44]. In other studies, the contents of corn cobs are described as including: (see table below) Cellulose nanofibrils in corn cobs have good potential as reinforcing fillers in bioplastic matrices [37]. Their high cellulose content makes corn cobs a natural cellulose source that can be used as a film [40].
The process of making biodegradable film from corncobs	1. Preparation stage In making biodegradable films, the corn cobs used must be flour [39]. Corn cobs can be extracted by soaking the mashed corn cobs for 24 hours. After 24 hours, the mixture is filtered, producing a residue. The residue is then oven-dried at 100^{0}C, and corn cob flour is obtained. Furthermore, the corn cobs are sieved using a sieve to obtain 100 mesh corn cob flour. [39] [46]. 2. Biodegradable film making *Plasticizers* are esters that can increase the elasticity of a material. Glycerol plasticizers also effectively reduce interactions between starch molecules and have hydrophilic properties [47]. Mukhlisien (2021) [47] explains the steps of making biodegradable films from corn cobs, namely: (1) Corn cobs that have been extracted (3 grams) are added with 50 ml of distilled water and stirred with a magnetic stirrer for 5 minutes; (2) The bioplastic mixture is added with 3 ml of acetic acid and 2 ml of glycerol, heated at 700C while stirring for 30 minutes; (3) Next, the solution is allowed to stand for 24 hours so that the air bubbles contained in it can be reduced; (4) After 24 hours, printing is done by

Composition	B2 [35]	B3 [36]	B12 [45]
Cellulose	40-44%	45%	38,33-40,31%
Hemicellulose	31-33%	35%	25,21-32,22%
Lignin	16-18%	15%	7,32-21,45%

	pouring the biodegradable plastic solution on a glass plate; (5) The biodegradable film solution will be dried for two days at room temperature.
Benefits of processing corn cob waste into biodegradable film	Corn cob is one of the biopolymers that can be used as raw material for making bioplastics [39]. The production of sustainable plastics contributes to efforts to achieve the SDGs [48]. The term "sustainable plastics" includes plastics produced from natural material sources to biodegradable raw materials [48] [49] [50]. The production of biodegradable plastics will reduce the environmental problems associated with conventional plastics [36] [40] [42]. Bioplastics utilize renewable resources such as agricultural waste and are biodegradable in various environments, making them more environmentally friendly than conventional plastics [40] [45] [50]. Developing waste-based bioplastics also reduces food waste simultaneously, thus promoting environmental sustainability [51]. Bio-based plastic products such as bioplastics contribute to growth and job creation [52]. From a circular economy perspective, using sustainable plastics with bio-based raw materials is an advancement [48]. Bioplastics support the circular economy by reducing waste, reducing greenhouse gas emissions, and preserving ecosystems and biodiversity [48] [52]. The growth of bio-based manufacturing with agricultural waste encourages investment in rural areas, spreading economic benefits widely [52]. The use of corn waste fibers results from environmental awareness and circular economy principles that direct the planning of waste-to-wealth strategies [35].

3. Category Selection

At this stage, structuring occurs based on the analysis in the previous stage. The deployment is done to identify the pattern of connection and interaction of all the elements coopted. In summary, the findings of the previous stage are classified into 5 sections, including: (1) The phenomenon of plastic waste, in this section describes the existence of plastic waste that occurs in Indonesia and the impact on environmental aspects; (2) Biodegradable film as an alternative to plastic, in this section explains the importance of biodegradable film as an alternative to conventional plastic; (3) The content of corn cob waste and its potential as a biodegradable film material, in this section describes the content of corn cob waste and the potential of corn cob as the main ingredient in making biodegradable films; (4) The process of making biodegradable film from corn cob, in this section it will be shown the stages of making biodegradable film from corn cob; (5) The benefits of processing corn cob waste into biodegradable film, in this section will describe the benefits of making biodegradable film from corn cob based on aspects of the environment, social and economy and its relationship with Sustainable Development Goals (SDGs).

4. Content Evaluation

This study aimed to create a concept map that would later be developed into Teaching Learning Sequences (TLS). They helped with relevant content evaluation to ensure that only relevant and reliable information was used in the analysis aligned with the research objectives. This process was oriented to the interpretation of the meanings of the evidence gathered in the previous stage, as well as to an elaboration of the Teaching Learning Sequences (TLS). Figure 3 depicts the outcome of the teaching-learning sequence (TLS).

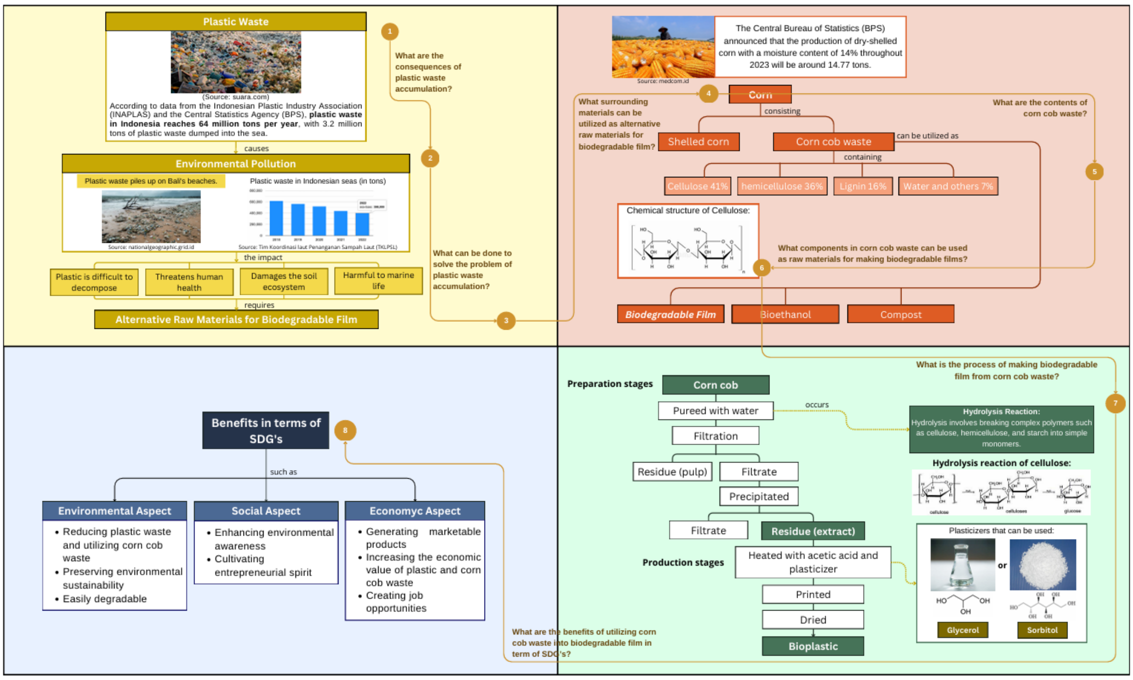

Figure 3. The Teaching-Learning Sequence of Biodegradable Film from Corn Cobs

The above Figure represents the Teaching Learning Sequences (TLS), comprising four interconnected conceptual sections that address critical issues related to biodegradable film production from corn cob waste. The first section highlights the environmental impacts of plastic waste accumulation and emphasizes the urgent need for alternative biodegradable materials. The second section explores the potential of abundant corn cob waste in Indonesia as a viable raw material for producing biodegradable films. Section three elaborates on the process of manufacturing biodegradable films from corn cobs, while section four underscores the alignment of this process with the Sustainable Development Goals (SDGs).

To enhance coherence and guide readers through the interconnected topics, questions linking sections of the TLS are represented by bold numbers in small circles, with connecting lines to respective sections. The initial question bridges sections 1 and 2 by addressing the environmental consequences of plastic waste accumulation. It transitions into section 2 with the question, “What can we do to solve the problem of plastic waste accumulation?” This leads to the exploration of bio-based raw materials as a solution. The third question connects sections 2 and 3, identifying corn cobs as an alternative biodegradable material. The next questions delve into the composition of corn cob waste, its suitability as a raw material, and the methodology for converting it into biodegradable film.

The final question links the entire TLS structure to the SDGs, discussing the environmental and societal benefits of transforming corn cob waste into biodegradable film. This TLS framework provides a structured approach for integrating project-based learning (PjBL) into chemistry education, focusing on real-world applications such as producing biodegradable films. It highlights the relevance of scientific inquiry and sustainable innovation in addressing global challenges.

One of the modern integrative learning relevant to global issues is the development of Teaching Learning Sequences (TLS) on making biodegradable film from corn cobs. High-quality environmental education has the potential to teach students scientific concepts while also inspiring sensitivity toward environmental issues and motivation to pursue science-based solutions. Using corn cobs for making biodegradable films in chemistry learning integrates learning between concepts and technology so that students can learn how to utilize waste corn cobs to overcome the plastic problem and add value to agricultural waste. [41]. One alternative raw material for making this film is corn cob, which has advantages in sustainability and reducing agricultural waste. Using corn cobs as a raw material for making biodegradable materials can be aligned with sustainable development because corn cobs are a large lignocellulose waste often underutilized. It was followed that the utilization of corn cob waste as a raw material for making biodegradable films [18] [36] [40] Could reduce the use of non-renewable resources such as petroleum and produce better biodegradable and biodegradable plastics. A circular economy turns what was seen as waste (the waste itself) into feedstocks for other processes, as agricultural waste turned into (for example) a new round of products. Producing biodegradable films from corn cobs contributes to the circular economy by minimizing waste, reducing greenhouse gas emissions, and conserving ecosystems and biodiversity. [38] [42].

Experts validated the Teaching-Learning Sequence (TLS) results. The Teaching-Learning Sequence (TLS) validation results are content-wise eligible for learning activities. TLS is divided into four concepts: 1) The phenomenon of plastic waste; 2) Corn cob components and potential use of corn cobs; 3) The process of making corn cob into biodegradable film; and 4) The benefits of processing corn cob waste into biodegradable film. The findings of the TLS in this study can be applied as an approach to developing learning designs or teaching materials in chemistry learning with the Project-Based Learning (PjBL) model for making biodegradable films from corn cob waste.

5. Project-based Learning: Implications

The formulation of the TLS for producing biodegradable film from corn cob facilitates the implementation of holistic and contextualized learning. This way, teaching materials can be better organized in a structured format, focusing on integrating their concepts and contextual application, supporting meaningful, sustainable learning. This TLS, by integrating theoretical and practical knowledge, enhances the effectiveness and significance of PjBL practice. It can also be carried out in a project-based learning context, where students work in groups on a biodegradable film project, design it, and carry it out afterward. This application develops collaborative, critical thinking, and problem-solving skills in students. This TLS on the subject can form part of an environmental education package. Education and TLS: This TLS focuses on applying knowledge to real-world situations and arms students with relevant practical skills after graduation. Students are more committed to the project since they are involved in topics of relevance and direct effect to their environment; they understand that what they are learning serves a practical purpose. It also cultivates an awareness of sustainability. For example, students are encouraged to devise alternative solutions to global issues like plastic waste, expanding their understanding of the effects of technological choices on the planet.

6. Restricts and Directions for Future Study

Though the results were positive, this study had many limitations regarding time and resources. Qualitative content analysis is time and resource-consuming, notably in the phases of data collection, data coding, and interpretation. In this case, a detailed and repetitive structure is required to produce a good output, and the severe time and resource constraints played a major role in the study's results. Future studies should investigate longer project timelines, which can provide researchers with opportunities for more comprehensive data analysis. According to Yang (2013), longer projects will no longer allow for subjectivity bias as researchers take longer to develop a perspective and triangulate data.

CONCLUSION

This study successfully developed a Teaching-Learning Sequence (TLS) to produce biodegradable films from corn cob waste. The TLS framework is organized into four key themes: addressing the environmental challenge of plastic waste, exploring the potential of corn cobs as a resource, detailing the process of producing biodegradable films, and analyzing the environmental and sustainability benefits of corn cob waste. The findings underscore the potential of TLS to enhance chemistry education through integrating project-based learning (PjBL). This approach fosters deeper student engagement and understanding by linking scientific concepts with real-world applications while promoting critical thinking about sustainable development. This research demonstrates the educational value of incorporating environmental and sustainability topics into chemistry curricula, contributing to developing eco-conscious and scientifically literate individuals.

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