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Development of Eco-Friendly Chemistry Teaching Materials: A Periodic Table Using Recycled Materials

Siti Marfu'ah*, Lupita Amelia, Andini Mitra, Shela Amalia, Titis A. Setyorini, Karimatul Alifah
Chemistry Education, Fakultas Ilmu Tarbiyah dan Keguruan, Universitas Islam Negeri Raden Fatah Palembang,
Jl. Pangeran Ratu, 5 Ulu, Seberang Ulu 1, Palembang 30252, Indonesia.

Corresponding author*
sitimarfuah@radenfatah.ac.id

Abstract: Chemistry education, particularly in learning the periodic table, requires instructional media that can visualize abstract concepts and facilitate students' understanding of the arrangement of chemical elements. This study aims to develop periodic table learning media using recycled materials, including cardboard and styrofoam. The development followed an exploratory approach through prototype creation, involving six students and one chemistry education lecturer. The development process consisted of three main stages: (1) needs analysis, including literature review and material characteristics analysis; (2) design, involving blueprint creation and technical specification setting; and (3) prototype development, consisting of material preparation, component fabrication, and assembly. The study resulted in a modular periodic table prototype measuring 70 cm x 100 cm, with removable element cards sized 8 cm x 8 cm. The developed learning media offers advantages in interactivity through its modular system, visualization through consistent color usage for element grouping, and sustainability through the use of recycled materials. Challenges in development included optimizing material durability and the locking system for element cards. The resulting prototype shows potential to support active and constructive learning while integrating principles of education for sustainable development in chemistry learning.

Keywords: chemistry teaching materials, periodic table, prototype development, recycled materials, sustainable materials.

Introduction

Chemistry education at the secondary school level faces a range of challenges, particularly in understanding abstract concepts that require visualization and deep comprehension. The periodic table of elements, a foundational tool in chemistry education, is essential for students to master in order to understand the properties and periodic trends of elements. However, conventional teaching methods often struggle to engage students actively in the learning process (Alisoy, 2023; Clark, 2023; Collins et al., 2023; Gumartifa et al., 2023; Hamid et al., 2023; Jegstad, 2024; Karpudewan, 2024; Owens et al., 2020; Sivarajah et al., 2019).

In the digital era, despite the availability of numerous applications and technology-based learning media, physical learning media retain distinct advantages, particularly in providing tactile experiences and facilitating collaborative learning within the classroom. Moreover, not all schools have equal access to technological facilities, making innovation in conventional learning media development highly relevant and necessary (Andrewartha & Wilmot, 2001; Castronova, 2002; Hameed et al., 2008; Mahrlamova & Chabanovych, 2021; Marfu'ah et al., 2022, 2023, 2024; Marfu'ah & Anwar, 2018; Marfu'ah & Meristin, 2022; Rueda et al., 2017; Yap, 2016; Zawacki-Richter et al., 2015).

One of the pressing global issues gaining increasing attention is environmental preservation, especially in waste management. The education sector holds substantial potential to contribute to addressing this issue by integrating sustainability principles into learning practices. Using recycled materials to create learning media not only provides an economic solution but also promotes environmental preservation and nurtures ecological awareness among students (Altassan,

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2023; Buriro et al., 2023; Cole, 2014; Foo, 2013; Saylan & Blumstein, 2011; Uda & Basrowi, 2024).

Discarded cardboard and styrofoam are two common waste materials found in everyday life. Cardboard is easily shaped, durable with proper care, and environmentally friendly as it naturally decomposes. Styrofoam, although environmentally challenging, can be repurposed to extend its usability before ultimately becoming waste. Utilizing these materials in educational media production exemplifies the implementation of green chemistry in education (Aubrecht et al., 2019; M. Chen et al., 2020; T.-L. Chen et al., 2020; da Silva Júnior et al., 2024; Kitchens et al., 2006; Loste et al., 2019; K. Matus et al., 2007; K. J. M. Matus et al., 2012; Riandi et al., 2022; Sheppard, 2020; Wardencki et al., 2005; Zuin et al., 2021).

The development of periodic table learning media using recycled materials offers several potential advantages. First, economically, recycled materials reduce production costs, making it more affordable for schools with limited budgets. Second, the production process can actively involve students, providing direct experience in the principles of reducing, reusing, and recycling. Third, the final product, a three-dimensional periodic table, offers a more interactive learning experience compared to conventional periodic tables in posters or books (Abdullah et al., 2011; Draper, 2004; Jansson et al., 2015; Karaarslan & Teksöz, 2016; Teksoz et al., 2010).

In the context of periodic table learning, three-dimensional visualization enables students to better understand the relationships among elements, periodic trends, and characteristics of each group and period. Learning media developed from recycled materials can also be designed to be modular, allowing for the addition of information or modifications according to learning needs (Izzah et al., 2021; Onofrei & Ferry, 2020; Shih et al., 2008).

This innovation aligns with the demands of the Merdeka Curriculum, which emphasizes active, creative, and contextual learning. The use of recycled materials in creating learning media can serve as a tangible example of integrating environmental education into chemistry education, while supporting the goals of the Sustainable Development Goals (SDGs) in quality education and responsible consumption and production (Kemendikbudristek, 2022).

Based on this background, this study aims to develop periodic table learning media using recycled materials, specifically cardboard and styrofoam. This development is expected to offer teachers an alternative solution for providing economical, environmentally friendly, and effective learning media to support chemistry education at the secondary school level.

Materials and Methods

Study area

This study was conducted at a university in South Sumatra, involving a team of five students and one supervising lecturer from the Chemistry Education Program. An exploratory approach (Armstrong, 1970) was employed to develop a periodic table prototype, without conducting empirical testing on student comprehension. The prototype development took place from February to May 2024, focusing on the exploration and design of the periodic table model.

Procedures

This research adopted an exploratory approach, concentrating on prototype development limited to the design phase. The process began with a needs analysis, which involved a literature review on periodic table instruction and the use of teaching media in chemistry education. Characteristics of recycled materials, such as cardboard and styrofoam, were analyzed to determine suitable processing techniques. The specifications for the learning media were then identified based on the requirements for teaching the periodic table, followed by collecting design references aligning with instructional objectives.

In the design phase, the team created initial sketches and layouts for the learning media. Proportional dimensions and scales were set to facilitate usability, planning the arrangement and coloring of elements to visualize groups and periods. Additionally, a modular system was designed to simplify assembly and construction, accompanied by a work plan and task distribution among the development team members.

The prototype development phase began with materials preparation, including the collection, cleaning, and preliminary processing of cardboard and styrofoam. The materials were then cut to the specified dimensions, and supporting tools were prepared. During component creation, a basic frame was constructed from cardboard as the base of the periodic table, while styrofoam was crafted into element cards, group and period markers, and additional labels and descriptions. Finally, the assembly process included arranging the periodic table frame, affixing element cards, attaching labels and descriptions, and conducting final product finishing and quality control.

Data analysis

Data collected throughout the development process were analyzed qualitatively with a descriptive approach, emphasizing several key aspects. First, in the development process analysis, comprehensive documentation was conducted for each stage, including identifying challenges encountered and solutions applied during production. The effectiveness of using recycled materials was also a focus, alongside an analysis of time and resources required. In the final product analysis, alignment with the initial design was examined, along with dimensional accuracy, craftsmanship quality, and product durability.

In the development potential analysis, areas for improvement were identified, and potential modifications and future development were evaluated. Additionally, the feasibility of replicating the product on a broader scale was considered. The findings from this analysis were presented descriptively, supported by visual documentation providing a comprehensive overview of the development process and outcomes for the recycled material-based periodic table educational media.

Results and Discussion

Result

The development of a periodic table educational media using recycled materials has resulted in a three-dimensional prototype that can be utilized for chemistry learning. The findings are presented according to the stages of the development process. In the needs analysis phase, the literature review identified that periodic table learning requires clear visualization to understand element ordering and relationships. Analysis of previous studies indicated that three-dimensional educational media enhances students' comprehension of chemistry concepts (Abdinejad et al., 2021; Fatemah et al., 2020; Kuit & Osman, 2021; Rahmawati et al., 2021; Teplá et al., 2022; Underwood et al., 2021). The recycled materials used showed that cardboard has a thickness of 3-5 mm with sufficient durability to serve as the basic structure, while used styrofoam, varying in thickness from 1-2 cm, was suitable for making removable element cards.

The media specifications identified include the need for a modular periodic table with proportional dimensions (70 cm x 100 cm), a consistent color-coding system to mark element groups, and essential information for each element, such as atomic number, relative atomic mass, and electron configuration. This analysis aligns with the study by Kusuma and Lipomi et al. (2020), which emphasizes the importance of visual and tactile aspects in chemistry learning.

In the design phase, a detailed technical design of the educational media was produced. The basic structure of the periodic table was designed with a modular system using layered cardboard that provides space for attaching element cards. Each element card, measuring 8 cm x 8 cm, was designed to clearly display information that is easy to read. The color scheme followed international conventions for element grouping, differentiating metals, non-metals, and metalloids by color.

The modular system developed allows element cards to be removed and reattached, supporting various learning activities, such as arranging elements based on electron configuration or identifying trends within a group. This design facilitates active learning, as recommended by Ippoliti et al. (2022), Jannah et al. (2019), Oktadio & Pardede (2024,) and Sahronih et al. (2019) in their research on interactive educational media.

The prototype development stage resulted in a three-dimensional periodic table educational media with distinctive specifications. The main frame, constructed from triple-layer cardboard with a total thickness of 1.5 cm, ensures structural durability. The element cards, made from styrofoam, are coated with colored paper and equipped with a simple locking mechanism, enabling easy attachment and detachment. Each element card presents key information, including atomic number, element symbol, element name, relative atomic mass, and outer-shell electron configuration. To enhance visualization, the cards were painted with durable acrylic paint, using consistent color codes for each element group. The periodic table prototype is documented in Figure 1.

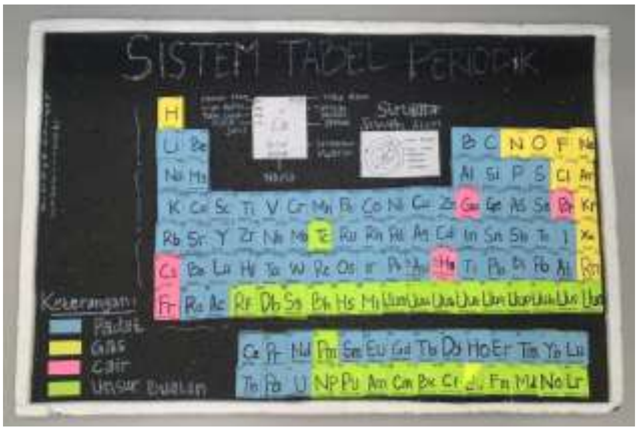

Figure 1. Prototype of Periodic Table

Discussion

The development of periodic table educational media using recycled materials has resulted in a prototype that demonstrates both advantages and challenges throughout its development process. This discussion is organized according to the development stages undertaken. The needs analysis phase revealed that using recycled materials in educational media not only provides economic benefits but also supports sustainable education practices. This finding aligns with Herranen et al. 2021), Karpudewan et al. (2009), Littledyke (2008), and (Zidny & Eilks, 2020), who found that integrating environmental aspects in chemistry learning enhances students' ecological awareness. The selection of cardboard and styrofoam as base materials was based on their availability and ease of processing, despite the challenges in ensuring the long-term durability of the educational media.

The design process adopted the instructional design principles outlined by Sweller (2002), emphasizing the importance of visualization and interactivity. The modular system developed allows flexibility in usage, supporting various teaching strategies such as cooperative learning and guided discovery. The design also considers ergonomic aspects, with size and proportions adjusted for classroom use.

The prototype development phase encountered technical challenges, particularly in processing recycled materials. The use of triple-layer cardboard was effective in providing a sturdy structure, consistent with Pratiwi & Yasin (2022) regarding optimizing recycled materials in educational media. The simple locking mechanism chosen for the element cards addressed durability challenges, although further development is needed to improve resilience for repeated use.

Special attention was given to the visual aspect of the developed educational media. Consistent color schemes for grouping elements help students identify patterns and regularities in the periodic table, as recommended by Scerri (2019). The information displayed on each element card was selected based on its relevance to high school education, focusing on essential foundational concepts.

The resulting prototype shows potential to support active and constructive learning. The modular system allows teachers to design a variety of learning activities, such as arranging elements based on periodic trends or identifying relationships between electron configurations and element properties. This approach aligns with the constructivist learning principles outlined by Pulungan (2021) in their study on interactive chemistry educational media.

Using recycled materials in the development of this educational media also adds value within the context of education for sustainable development. In addition to producing cost-effective educational media, this development process serves as a model for integrating sustainability principles into chemistry education, as recommended by Anastas and Etzkorn & Ferguson (2023), Karpudewan

(2024), and MacKellar et al. (2020) in their study on green chemistry education.

Conclusions

The development of periodic table educational media using recycled materials has resulted in a prototype that meets criteria for interactive, economical, and environmentally friendly learning media. The development process, which included needs analysis, design, and prototype development stages, produced a modular educational tool with technical specifications that support active learning. The use of recycled materials, such as cardboard and styrofoam, not only offers an economical solution but also promotes the implementation of sustainable education. Despite challenges in durability, the resulting prototype demonstrates potential for application in chemistry learning and may serve as a model for developing educational media that integrates sustainability aspects.

Conflict of Interest: The authors declare that there are no conflicts of interest concerning the publication of this article.

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