AR E-books Offer a Safe, Eco-friendly Solution to Combat Oxidation in Children's Storybooks for Green Libraries

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***Abstract*-. This research explores the application of Augmented Reality (AR)--based e-books as a sustainable and safe alternative to printed books within the context of green libraries. Green libraries aim to minimize environmental impact by optimizing energy use, efficient waste management, and leveraging digital resources. Although printed books remain popular in supporting children's literacy, they pose health risks due to the chemical content of materials like formaldehyde and benzene. Thus, this study evaluates the health risks associated with printed books and examines the potential of AR e-books as a safer and more eco-friendly solution for children. The method employed is a literature review, which includes product life cycle analysis, health risk evaluation, and user engagement assessment through AR technology. The findings reveal that AR e-books reduce carbon footprints and paper consumption, provide a more interactive learning experience, enhance children's reading interest, and eliminate the risks of exposure to harmful chemicals. AR e-books in green libraries can support environmental sustainability public health, and extend the lifespan of literary collections without physical degradation.**

Keywords; AR e-books, Children, Green Library, Health, Sustainability.

I. INTRODUCTION

Green libraries represent a significant initiative in environmental sustainability, where implementing sustainable practices is paramount to minimizing negative impacts on the environment. A key aspect of green libraries is optimizing energy use and efficient waste management. In this regard, libraries must adopt technologies and practices that support sustainability, including the transition toward a paperless ecosystem. Research indicates that using printed books can pose health risks due to hazardous chemicals found in paper, such as formaldehyde and benzene, which can be released through oxidation [1]. This is particularly concerning for children, who are more vulnerable to exposure to these toxic substances [2]. The health risks associated with printed books compel green libraries to consider safer and more environmentally friendly alternatives, such as Augmented Reality (AR)--based e-books. AR e-books not only mitigate the risk of exposure to harmful chemicals but also have the potential to reduce paper consumption and lower carbon emissions.

Studies have shown that AR e-books can create interactive and engaging reading experiences, enhancing children's interest in reading [3]. Furthermore, e-books provide easier information retrieval and better accessibility than printed books, improving the learning experience [4]. Implementing AR e-books in green libraries also supports children's digital literacy development. By leveraging AR technology, libraries can create more engaging and interactive learning environments, increasing children's involvement in reading [5]. Research has demonstrated that e-books facilitate better access to information and enhance digital literacy skills, which are crucial in today's information age [6]. Therefore, green libraries must formulate better strategies to support environmental sustainability and public health by considering AR e-books a safer and more sustainable alternative. Green libraries should also focus on developing policies and practices that promote sustainability in this context. This includes training library staff to understand and implement sustainable practices in their collection management and services [7]. Research indicates that libraries adopting green practices contribute to environmental sustainability and enhance their reputation within the community [8].

Consequently, green libraries can serve as models for other institutions in implementing sustainable practices and educating the public about the importance of sustainability [9]. Despite the challenges in implementing green practices, such as budget and resource limitations, libraries can overcome these barriers through effective collaboration and partnerships [10]. Studies have shown that libraries engaged in sustainability initiatives often find innovative ways to address these challenges and create positive impacts in their communities [11]. Therefore, libraries must continue exploring and adopting sustainable practices that can enhance public health and environmental well-being. To evaluate the health risks posed by using printed storybooks and explore AR e-books' effectiveness,

further research is needed to understand the impacts of both formats. By comprehending the risks and benefits associated with printed books and e-books, libraries can develop better strategies to support environmental sustainability and public health. This research can also provide valuable insights for policymakers in designing policies and practices that support green libraries. Overall, green libraries have significant potential to contribute to environmental sustainability and public health by implementing sustainable practices and using innovative technologies. By adopting AR e-books as a safer and more sustainable alternative, libraries can create better learning environments for children and society. Therefore, libraries must continue innovating and adapting to technological advancements and community needs to support sustainability.

II. RESEARCH METHODS

This study uses a literature review method by analyzing various scientific sources related to the health and environmental impacts of using printed storybooks and AR e-books. The steps taken include:

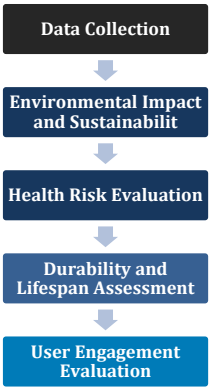

Figure 1. Steps in this method

A. Data Collection

Data was collected from scientific journals, research reports, and other publications relevant to green libraries, the chemical impact of printed books, and the implementation of AR technology in education. The literature reviewed covers the environmental impact of paper production, the health risks of chemicals in paper, and studies on the effectiveness of AR in enhancing children's reading engagement.

B. Environmental Impact and Sustainability

Through Life Cycle Assessment (LCA), this study compares printed book production's environmental impact with AR e-books. This analysis focuses on the carbon footprint generated by the production, transportation, and distribution of printed books and how AR e-books reduce these impacts.

C. Health Risk Evaluation

The study examines hazardous chemicals commonly found in paper, such as formaldehyde and chlorine, and how long-term exposure to these substances affects children's health. This data is compared with the near-zero risk posed by AR e-books, which do not contain harmful physical materials.

D. Durability and Lifespan Assessment

This study compares the durability of printed books, which are prone to physical damage and degradation due to oxidation, with AR e-books, which are digital and more durable. The lifespan of electronic devices is also considered, with an evaluation of the average lifespan of devices such as tablets or smartphones.

E. User Engagement Evaluation

The study also reviews how AR enhances children's reading experiences. Literature on the impact of visual and audio interactions from AR e-books on children's reading interest and comprehension is used to evaluate the potential benefits of AR technology in green libraries.

The findings from this research can build a strong argument for the benefits of AR e-books in improving health, sustainability, and children's literacy experiences in green libraries.

III. RESULT AND DISCUSSION

This research focuses on using Augmented Reality (AR) e-books as an environmentally friendly solution to address the oxidation issue in children's storybooks in green libraries. The findings of this study are discussed through several key points, including environmental impact and sustainability, durability and lifespan, user engagement and learning experience, and the practical implications of implementing AR e-books in green libraries.

A. Environmental Impact and Sustainability

Traditional children's storybooks printed on paper have a significant environmental impact. Paper production requires large amounts of energy and water, contributing to deforestation and carbon emissions. According to research, the production and distribution of a single paper book typically generate between 7.5 and 9.5 kg of CO2 [12]. Additionally, physical damage to books caused by oxidation and environmental changes such as humidity and temperature often force libraries to replace damaged books, which adds to waste and operational costs. Paper-

based storybooks can be considered less sustainable than digital alternatives in this context.

In contrast, e-books with augmented reality (AR) technology offer a more environmentally friendly solution. AR e-books do not require physical raw materials like paper; their distribution only requires digital devices such as tablets or smartphones that can be used repeatedly [13]. Thus, this technology aligns with sustainability principles by reducing carbon emissions from producing and transporting physical books. While electronic devices also have a carbon footprint, they tend to have a longer lifespan. They can be used for various other functions, making their environmental impact more efficient than physical books.

In the context of green libraries, AR e-books support resource efficiency and energy savings. Paper books require significant storage space and controlled temperature and humidity to prevent damage. In contrast, AR e-book collections can be stored on digital servers without requiring substantial physical space. This aligns with green library goals to reduce environmental impact and promote sustainable resource usage. Furthermore, using AR e-books in libraries can reduce paper consumption, waste, and carbon emissions from the physical book production process.

From a health perspective, paper books often contain harmful chemicals such as chlorine, formaldehyde, and heavy metals used in bleaching and printing. These substances can pose health risks to children, who often have habits of touching and biting books. In contrast, AR e-books do not contain these harmful chemicals, making them safer for children. Additionally, digital devices that read e-books can be cleaned regularly, maintaining hygiene and reducing the risk of spreading germs or allergens.

Comparing traditional storybooks and AR e-books shows that AR e-books offer greater sustainability and user health benefits. AR e-books in green libraries can reduce paper consumption, waste, and carbon emissions while minimizing health risks from exposure to chemicals commonly found in physical books.

B. Durability and Lifespan

Traditional children's storybooks, especially those intended for young readers, have significant limitations in terms of lifespan due to the physical properties of paper, which are prone to damage. These books often need help with wear and tear due to repeated use, rough handling, and exposure to less-than-ideal environmental conditions. The oxidation process in paper causes books to yellow, become brittle, and tear easily [14]. Furthermore, fluctuations in temperature and humidity and exposure to sunlight accelerate physical damage to paper books, particularly in libraries frequently used by children [15].

In contrast, Augmented Reality (AR) e-books offer a much more durable solution because they are digital. AR e-book content is not susceptible to the physical damage that affects paper books. AR e-books do not degrade in quality due to oxidation, environmental exposure, or repeated use, giving them a much longer lifespan [16]. As a result, green libraries that adopt AR e-book technology can reduce the frequency of book replacements and minimize paper consumption and the associated waste.

The durability of AR e-books depends largely on the electronic devices used to access them, such as tablets or smartphones, which typically have a lifespan of 4-7 years [17]. As long as these devices function properly, AR e-book content can be accessed continuously without any degradation in quality. Therefore, regarding content longevity, AR e-books far surpass physical books, which often require replacement due to damage or wear [18].

The advantages of AR e-books in terms of durability within green libraries include several aspects. First, AR e-books are free from physical damage, such as tearing or staining, which commonly occurs with physical books, especially when handled by children [19]. This extends the lifespan of the content and reduces the need for book replacement or repair. Second, AR e-books are unaffected by oxidation, eliminating the need for environmental controls like temperature and humidity necessary to preserve physical books in traditional libraries [20]. Third, AR e-book content can be updated digitally without reprinting, reducing resource waste and production costs [21]. Finally, the electronic devices that access AR e-books can store hundreds to thousands of books in a single unit, making them highly efficient in space and resource usage.

However, there are some challenges related to the durability of electronic devices. Devices such as tablets and smartphones require regular maintenance and battery charging. If the device experiences technical issues, access to AR e-book content may be disrupted. Nevertheless, with proper care, these devices can last for several years [22]. Additionally, AR e-book use requires supporting technological infrastructure, including internet access to download or access content and compatible devices [23]. The initial investment cost for electronic devices is relatively high. However, this can be offset in the long term by reducing the need for physical book replacements and collection maintenance costs .

AR e-books offer superior durability compared to traditional children's storybooks. Due to their digital nature, AR e-books are not prone to physical damage or degradation from environmental factors, resulting in a longer lifespan. Green libraries adopting AR e-books can reduce waste, enhance resource efficiency, and lower book replacement costs. However, challenges related to electronic device maintenance and technological infrastructure must be managed effectively to realize this technology's benefits fully.

C. User Engagement and Learning Experience

Augmented Reality (AR) e-books offer a far more interactive and engaging reading experience than traditional storybooks. AR e-books create a more immersive world for young readers by integrating visual, audio, and textual elements. For example, characters in the book can "come to life" through AR animations, sounds, and other visual effects, which enhance children's engagement with the story [24]. Research indicates that AR e-books can increase children's interest in reading, improve their comprehension of stories, and assist with language learning. AR e-books can hold children's attention longer than traditional paper books, thanks to interactive features like the ability to move or touch elements on the screen, significantly enhancing their engagement with the content [25].

AR technology has enhanced interactive and engaging student learning, particularly in children's literacy. AR e-books offer a more captivating reading experience and support the development of better literacy skills. A study found that children using AR e-books improved their early literacy skills, which are crucial for their academic and future success [25]. Furthermore, AR e-books allow children to interact with the book's content, enriching their learning experience and making reading more enjoyable [26].

While paper books hold sentimental value and offer a unique tactile experience, the engagement provided by AR e-books tends to be higher, especially for younger generations growing up in a digital environment. AR e-books in libraries can expand access to a more diverse range of storybooks tailored to individual reader preferences, including customizable text options, audio narration, and translations in various languages [27]. Thus, AR e-books serve as learning tools and a medium to enhance children's reading experience and overall engagement.

D. Practical Implications for Green Libraries

Adopting Augmented Reality (AR) e-books in green libraries presents various practical implications that align with sustainability goals and environmental preservation. One of the main advantages of using AR e-books is the reduction in operational costs. Libraries that have integrated AR e-books report that they no longer need to allocate funds to maintain and replace damaged paper books, which can often involve significant expenses [28]. Additionally, AR e-books can be accessed by multiple users simultaneously through shared or personal devices, allowing for more efficient use of space and resources [29]. This is particularly important for green libraries, which often have limited space and prioritize eco-friendly design.

AR e-books also offer flexibility in terms of storage and accessibility. Digital collections can be stored in cloud computing systems, eliminating the need for large physical spaces like traditional bookshelves [30]. As a result, green libraries can optimize available space for more productive and environmentally friendly activities. Research indicates that the transformation of books into digital formats improves storage efficiency and reduces the carbon footprint associated with the production and distribution of printed books [30].

However, the adoption of AR e-books also presents certain challenges. Initial investments in digital devices, staff training, and technological infrastructure must be considered [28]. Nevertheless, these costs are often offset by long-term savings and the sustainability benefits of AR e-books compared to traditional paper book collections [31]. Another challenge lies in users' acceptance of the technology, particularly among older generations, who may feel uncomfortable with new technology [29]. Therefore, libraries must provide adequate training and support to ensure all users can effectively utilize AR e-books.

Overall, despite the challenges associated with adopting AR e-books, their sustainability and operational efficiency benefits make them an attractive option for green libraries. With the right approach, libraries can integrate this technology to support their sustainability goals while enhancing user experience. This makes the story more interesting and captivating, particularly for young readers who tend to enjoy interactive and entertaining visual elements [32]

E. Creation of AR E-books as a Solution

Augmented Reality (AR) e-books provide an innovative solution to address health and environmental concerns associated with using paper books. Key benefits of AR e-books include:

1. Safety from Harmful Chemicals: AR e-books eliminate the need for paper, ink, and adhesives that may contain harmful chemicals, making them safer for children, especially those sensitive to such substances.
2. Reduction of Paper Waste and Deforestation: Using a digital format, AR e-books help reduce tree cutting and paper waste while lowering the carbon footprint associated with producing and distributing physical books. AR e-books contribute to sustainability by reducing the need for paper, which in turn decreases deforestation and waste generation. By offering digital solutions, AR minimizes the carbon footprint associated with printing and distributing physical books, aligning with broader environmental protection goals [33]
3. Enhanced Engagement and Reading Experience: With interactive features like visuals, audio, and animation, AR e-books make reading more engaging, increasing children's interest and improving their

comprehension of stories. The interactive nature of AR e-books—incorporating audio, visuals, and animations enhances engagement and improves comprehension, particularly for young readers. Moreover, AR e-books can be adapted for accessibility, including features like audio narration and adjustable text size, making them suitable for children with special needs [34]

4. Easy Content Updates: AR e-books allow for easy and cost-effective updates without the need for reprinting, reducing waste and expenses.
5. Accessibility and Inclusion: AR e-books can be accessed on various devices, offering customizable features like audio narration and larger text, making them inclusive for all children, including those with special needs.

Figure 2. Storybooks that have implemented AR technology.

Creating children's storybooks integrating Augmented Reality (AR) technology involves a combination of visual narration with animation and interactive digital elements that can be accessed through devices like smartphones or tablets. Users must first install an AR application on their smartphone to activate the AR feature. Once the app is installed, users can scan the images available on each book page. For example, in the storybook "Kupu-kupu Penyelamat," each printed page has AR elements accessed by scanning the images with the smartphone camera. After scanning, the animal characters in the story can be visualized in three-dimensional (3D) form, creating an interactive experience where the characters seem to come to life on the device screen.

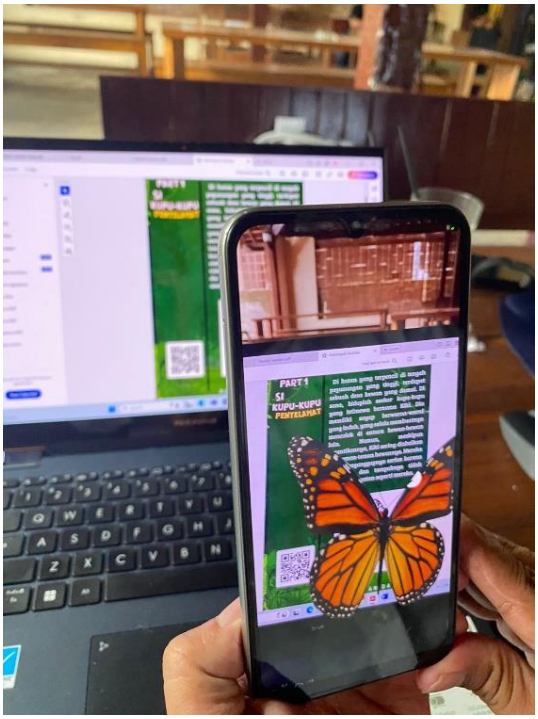

Figure 3. Visualization of a smartphone pointed at the images in the storybook.

Based on the visualizations, AR technology brings characters in the story to life, such as butterflies, owls, and ants, which appear in three-dimensional (3D) form when the images are scanned using a smartphone camera. The resulting images come alive on the device's screen, providing readers with a more dynamic and interactive visual experience. For instance, the butterfly character appears with flying wings, creating an immersive effect. AR technology enhances reader engagement, especially for children, as they read the story and see the animal characters move as if they exist in the real world. This makes the story more interesting and captivating, particularly for young readers who tend to enjoy interactive and entertaining visual elements.

The narrative remains in text form, but adding 3D visuals of characters, such as butterflies, owls, and ants, provides a richer visual context for the story. Readers understand the story through words and see visual representations of the characters involved. The implementation of AR technology in this book serves as entertainment and an educational tool. Storybooks can help children become more familiar with animals, understand their characteristics, and learn important values such as cooperation and bravery through the tale of Kiki the butterfly, which helps save other animals from the danger of a flood.

IV. CONCLUSION

The use of Augmented Reality (AR) e-books has proven to be effective as an environmentally friendly solution in green libraries. AR e-books reduce the negative impacts of printed book production, such as carbon emissions, deforestation, and paper waste, while reducing energy and resource consumption. Regarding health, AR e-books eliminate the risk of exposure to hazardous chemicals in printed book paper, such as formaldehyde and chlorine, making them safer for children. In addition, AR technology increases children's engagement in reading with dynamic visual and audio interactions, creating a more immersive learning experience. AR e-books also have a longer lifespan than printed books because their digital content does not experience physical degradation. By adopting AR technology, green libraries can save space and operational and maintenance costs and support sustainability by reducing resource consumption and carbon emissions. The implementation of AR e-books supports green libraries' sustainability goals and enriches children's educational experience while contributing to environmental conservation and health improvement.

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