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Manifestation of Circular Economy in Repurposable Green Furniture Design, A Project-Based Learning by Interior Design Student

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Abstract

This article reveals the embodiment of circular economy in interior design students' design of reused green furniture. The circular economy is becoming important, mainly in dealing with the problem of inorganic waste. The main focus is how the circular economy concept can be taught through actual practice, where students collaborate with stakeholders, namely TPS3R and the green industry, to design environmentally friendly and sustainable furniture. This applied research uses the double-diamond method from the UK Design Council to guide the design process, including Discovery, Definition, Development, and Delivery, emphasizing the first diamond for field research and the second diamond for design development. This method has enabled students to understand and practically apply circular economy principles. The applied research was conducted over 16 weeks for field research and studio work on campus. Although all the research results are not yet satisfactory, they show that this project-based learning approach effectively improves students' understanding of sustainability and innovation in furniture design. In addition, the collaboration with the green industry also enriched students' learning experiences and strengthened the link between education and industrial practice in sustainable design.

1. INTRODUCTION

To address increasingly serious environmental problems, experts introduced the circular economy concept. The main principle of the circular economy is to reduce the use of raw materials, redesign the use of natural resources in products, and recycle as much waste as possible. The practice of reducing, reusing, and recycling is now widely adopted by communities as part of the circular economy movement, accompanied by initiatives such as the waste bank movement and frugal living. These efforts aim to realize a prosperous society, social justice, and living in a sustainable environment. In this context, design objects and activities play an important role in the success of the circular economy, as appropriate design can help maximize resource use and reduce environmental impact. Therefore, design students must understand and then apply the circular economy concept in their work. By doing so, they can contribute significantly to more sustainable environmental solutions in the future.

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Global experts emphasize that a circular economy is critical to human sustainability and environmental preservation [1], [2], [3]. The circular economy is considered one of the leading solutions to the resource crisis and climate change. Meanwhile, some designers underline that designers play a key role in shaping the artificial world [4], [5], [6]. Therefore, they should also be involved in creating more sustainable systems and products. Ellen MacArthur stated that architects and designers are indispensable in transitioning to a circular economy. To the younger generation, she said, 'What a fantastic opportunity to be part of building a restorative and regenerative future; a future where we can recover materials and channel them back into the economy' [1]. This statement emphasizes the importance of young designers, in this case, design students, in making the world's green transition successful. Many articles have been written about design and the circular economy, but not many have addressed the work of design students and the circular economy. Many articles have been written about design and circular economy, but not many have discussed the work of design and circular economy students.

The purpose of this article is to reveal the applied research that has been carried out by lecturers and students of S-1 interior design FRSD ISI Yogyakarta in addressing the environmental problems that exist around them, namely the problem of waste, as well as finding design solutions that can be used to answer these problems. The research problems are as follows: How is the project-based learning process that DI students can carry out by applying a circular economy approach in furniture design projects? In this context, the double diamond method is applied as a framework to support the design practice. This method allows students to go through the problem-exploration and solution-finding stages in depth and gradually. In this research, interior design students work in groups, connecting their projects with actual conditions in the field, conducting research at the Waste Management with 3R Principles (TPS3R), the recycled material industry, and residents of simple rental flats (Rusunawa). Through this circular economy approach, the principle of recycling as much waste as possible, students can understand the problems and needs of society and the challenges faced in finding solutions. The result is a functional and appropriate furniture design for a young urban family home, considering sustainability and environmental impact. This process not only practices design skills but also increases the social and environmental awareness of the students.

This article states that the project-based approach or practical fieldwork effectively enhances students' understanding of sustainability and innovation in furniture design. Through direct involvement in real projects, students learn about theory and how to apply those principles in practical situations. This approach gives them more profound insights into the challenges of creating sustainable products and encourages them to think creatively and seek innovative solutions. In addition, collaboration between educational institutions and environmentally friendly industries provides significant added value. Students can learn directly from experienced professionals in the field, enriching their learning process. This relationship also strengthens the ties between the education sector and industry, ensuring that what is learned in the classroom is relevant to real-world practices. In the context of sustainable design, this collaboration becomes an important foundation in creating a generation of designers who are more responsible towards the environment.

2. LITERATUR REVIEW

2.1. Circular Economy

In his book, Keraf defines circular economy as an economic system that aims to minimize waste and resource use by redesigning production and consumption processes [7]. Meanwhile, Kirchherr said that SE is an economic system that replaces the concept of 'end-

of-life' with the concept of material reduction, reuse, recycling, and recovery in the entire production, distribution, and consumption cycle [3]. Other scholars put it succinctly that end-of-life goods are transformed into resources for others, forming a closed loop and minimizing waste [8]. In the circular economy concept, products and materials are designed to be reused, recycled, or renewed to maintain the value of materials for as long as possible. This approach differs from the linear economic model practiced by the general public, which follows the 'take, make, dispose of.' The originators of the circular economy seek to create a more sustainable system by reducing the use of natural resources, reducing waste, and minimizing the environmental impact of economic activity.

In the circular economy, waste is one of the main focuses, whereas in the linear economy, products that have been used up often end up as waste that is then disposed of in landfills. In contrast, in the circular economy, waste is seen as a resource that still has value and can become a business. Szerakowski divides the circular economy into 7 things: 1. prioritizing regenerative resources, 2. preserving and expanding what has already been created, 3. Using waste as a resource, 4. Designing for the future 5. Collaborating to create shared value 6. Rethinking business models 7. Incorporating digital technology [9].

Meanwhile, Keraf mentioned that there are 5 business models in the circular economy, one of which is the recovery and recycling business model. In this business model, the general public is asked to be able to recycle and reuse old products and materials that they have so that the amount of waste generated can be significantly reduced. In addition to waste reduction, this can also be used to reduce the need for new raw materials, reducing pressure on natural resources [7].

2.2. Green Material Reuse

Material reuse can preserve the remaining attributes of a product by extending its life cycle while delaying the disposal stage. It can also generate additional revenue, which can later be used for recycling and sustainable disposal [10]. However, reusing the new material must be compatible with the original material. Processing this new material is a recommended business model in the circular economy. As stated by Keraf, one of the results of the recovery and recycling business model is repurposable green materials, which are materials produced from recycling processes or renewable and environmentally friendly [7]materials. In a circular economy, using repurposed green materials is very important as it can help reduce dependence on non-renewable raw materials and reduce the carbon footprint. Green repurposed materials can include a wide range of materials, such as recycled plastics, recyclable paper, or biomaterials made from renewable biological resources. Green material processing companies in Indonesia were not established long ago, and few products have been produced.

The circular economy is a new system that requires collaboration from various industry sectors, including suppliers, manufacturers, recycling processors, distributors, retailers, end consumers, and waste collection service providers [8]. The system aims to create a sustainable cycle in resource management. Environmentally friendly materials that can be diverted will pass through each stage in this chain. Starting from the collection of waste, sorted according to its type, the waste is sent to the recycling industry to be processed into new materials. These materials, called repurposed green materials, are then used to produce new goods. Thus, this recycling process creates a sustainable cycle. Products that consumers have used go back into the system for reprocessing, creating a more efficient economy and reducing waste in landfills.

2.3. Furniture Design

Furniture in an interior space is designed to withstand structurally strong loads and provide comfort when used. According to Ching, furniture must fulfill ergonomic standards, considering the user's body size and the activities performed. Furniture design also needs to pay attention to cultural factors and the style preferred by its users to make it more relevant and suitable for the needs of the space [11]. Wang added that furniture is the main element in interior design, where furniture can serve to provide the dominant color that shapes the atmosphere of the room [12]. Thus, the selection of furniture impacts not only its practical function but also the room's overall aesthetics. In addition, control over the amount of furniture used and the style chosen dramatically affects the comfort level within a space, especially in a residential home. Proper selection can create harmony between the space's visual beauty and physical comfort.

The furniture makes the interior habitable by providing comfort and utility for the work and activities [11]. Furniture can personalize space as it reflects the owner's preferences, activities, and needs [13], next about furniture for residential houses. Each room in the house has different functions and furniture needs. For example, the dining room requires comfortable tables and chairs for dining activities, while an ergonomic bed is needed in the bedroom to support sleep quality. In the living room, sofas and tables are important elements to receive guests comfortably, while in the work or study room, tables and chairs that support posture are needed to support productivity. In addition, storage furniture such as wardrobes or food shelves is an essential component that helps keep the home tidy and organized. With so many activities taking place in the home, choosing the right furniture can enhance the comfort and functionality of each space and create an environment that suits the needs of the occupants.

2.4. Project-Based Learning

Project-based learning aims to help learners find solutions to real problems while learning problem-solving concepts. This approach encourages learners to hone their critical and creative thinking skills. In the learning process, they work collaboratively in groups, analyzing problems relevant to everyday life. This method allows students to find solutions more actively than passively receiving knowledge. By learning from the surrounding environment, students are expected to be more involved in learning, understand the broader context, and apply the knowledge they gain [14]. The project-based learning model is an innovative student-centered approach, where the teacher's role is more as a motivator and facilitator of the learning process. In this model, students can develop their learning independently, so they are more active in exploring knowledge [15]. This model often uses real problems as a learning tool to facilitate understanding and accelerate theory absorption. Using a contextual approach, students learn theoretically and relate knowledge to real situations. This approach is effective in helping students develop critical and analytical thinking skills [16].

3. RESEARCH METHODOLOGY

The activity is applied research that is simultaneously integrated with the learning process of project-based courses and entered into one of the MBKM activity categories, namely independent projects. This Independent Project was carried out by 5 Interior Design Study Programme FSRD ISI Yogyakarta students, accompanied by 2 supervisors. In addition to collaborating with industries that produce recycled waste materials, this activity is also supported by the local government. The project was carried out for one semester or 16 weeks. This Independent Project also contains 5 courses; the total SKS (Semester Credit Units) are 10sks. The five subjects are Ergonomics, Design Management, Design Thinking,

Furniture Design, and Presentation Techniques (MBKM FSRD ISI Yogyakarta Implementation Manual, 2023).

This applied research uses the Double Diamonds method, a problem-solving framework created in 2004 by the Design Council UK. This method is very popular, and many people have adopted it; in essence, each diamond describes exploring the problem broadly and deeply (divergent) and then taking focused action (convergent). This method has four steps: Discovery, Define, Develop, and Deliver [17]. These four simple steps are concise and suitable for undergraduate student design projects. Compared to other methods, such as the 5 steps of Design Thinking (Emphatize, Define, Ideate, Prototype, Test), which are more detailed, especially in prototyping. Moreover, Double Diamonds also feels more comprehensive than DK Ching's method (Analyse, Synthesise, and Evaluate), which seems too brief.

The stages of implementation are as follows: 1) Discover and find out the principle of circular economy in design practice, then continue with understanding the problem of inorganic waste and its upcycling process and identifying the technical specifications of the green reusable materials produced. This was followed by a study of the tastes and needs of the design users (young urban families as home furniture users) and listing their needs for home furniture. 2) Define, armed with the results of the first stage, the researcher will formulate the problems to be solved and the concept of urban young family home furniture design. 3) Develop and develop alternative and selected ideas starting from the existing problems, endeavoring to propose new perspectives using repurposed green materials. 4) Deliver and test several alternative designs and prototypes offered.

4. RESULT AND DISCUSSION

4.1. Waste in the Circular Economy

Figure 1. The TPS3R Giwangan building, waste sorting activities, and waste volume data. [Source: PSDI Research Team, 2024]

The TPS3R building adjacent to the Giwangan market is in the southern part of Yogyakarta. Inside this building, in addition to collecting waste, there are also waste sorting activities carried out by the employees. The TPS3R manager also uses a small office. On the blackboard mounted on the office wall, some data mentions the amount of waste that enters this TPS3R and the efforts to reduce waste and further process waste into new materials. Many types of waste are coming in, the most common being organic waste and the second being non-organic plastic, paper, glass, and metal.

TPS3R Giwangan is one of the waste collection sites managed by the Yogyakarta city government. The waste collected in this area comes from markets; the volume of waste managed daily ranges from 25-30 tonnes, and the waste comes from 29 markets in Yogyakarta. TPS3R Giwangan has a staff of 15 people, among others, working on waste segregation. As listed in the data, waste sorting is divided into 4 categories: organic, inorganic, recyclable waste, and residual waste. Especially for inorganic waste because they do not have the technology yet, so further processing of inorganic waste has not been done

at this place; this type of waste is channeled to waste banks and non-governmental institutions, who then process inorganic waste into new materials.

With the increasing population of Yogyakarta, the amount of waste will surely increase. The increase in the amount of waste in the city, which is not accompanied by the development of progressive waste management technology, has brought disaster to the city of Yogyakarta, namely the emergence of a waste emergency. A situation in which the waste landfill in Piyungan Bantul is full and cannot accept any more waste disposal. As a result, the city's citizens, through PEMDA, cannot dispose of waste as usual. The emergency condition has been occurring since mid-2023 and reached its peak in May 2024. Since this event, the issue of proper waste management has become increasingly necessary and needs to be implemented immediately; the community, together with the local government, then looks for various ways to manage this waste or waste into new materials that can be utilized from organic and non-organic waste. This is where the circular economy, specifically the Recovery and Recycling business model, becomes a real challenge to put into practice.

4.2. The Processing of Inorganic Plastic Waste into Repurposable Green Materials

Figure 2. Plastic waste from bottle caps, plastic pellets ready for processing, furniture made from repurposed green materials.
[Source: PSDI Research Team, 2024]

The selected plastic waste in the photo is mineral water bottle cap waste. This is the highest grade of waste, HDPE. Waste sorted according to type is then chopped into smaller parts and even granules, such as seeds, pellets, powder, or fractions. The second photo is waste that has been chopped into powder form and is ready to be processed into new materials. The third photo is an example of a new re-purposed green material utilized as a tabletop; many other products can be made using this new material.

Field observations show that the new material processing industry supplies selected plastic materials from waste collectors or banks. The selection of these materials is differentiated because each will go through different processes and produce different new materials; of course, this new material will be utilized according to the type of plastic. At Inastek, the separated plastic waste is then shredded, washed, dried, melted, and cooled; the last part is forming new materials according to the desired design. Mentioned by Intimas Company that there are 7 types of plastics produced from the processing of used plastics, of which only 3 types can currently be put to good use here, namely: The new material that will be used in this project is HDPE, which is a type of plastic that is easy to find, easy to shape, resistant to corrosion, resistant to water, and easy to recycle.

The current waste plastic processing business model can already produce various small-size products, such as accessories and room equipment, including plant pots, soap holders, tissues, pencils, and large enough products for furniture. The manufacture of furniture usually uses the material in the form of boards or boards, where these plastic boards are usually cut according to the size of the furniture to be made. This new material can be a substitute for materials in general, and its size and shape can be adjusted to the needs of the industry. This material for furniture can be used as a whole without being combined with other materials. However, it can also be combined with other materials such as wood,

iron, aluminum, etc. This newly developed material has undergone laboratory testing, so its load resistance and durability can be relied upon. When this material has reached the end of its useful life and can no longer be used, it can be recycled again with a lower material quality.

4.3. The Process and Results of Designing Furniture Made from Repurposable Green Materials.

Table 1. Four Steps of the Design Process along with the details of the activities [Source: PSDI Research Team, 2024]

	Discover	**Define**	**Develop**	**Deliver**
Activities	- Circular economy in design practice - Issues of inorganic waste and the upcycling process - Identification of technical specifications for green alternative materials - Studying the tastes and needs of users, specifically urban young families	Issues in furniture design and the concept of furniture design.	Realizing ideas in the form of sketches, working drawings, and 3D images, and determining design specifications to proceed with the creation of a 1:1 prototype.	Evaluating a work using several criteria.
Methods	Interview, field survey, observation	Create a program and identify the theme.	Developing the design and detailing the dimensions, materials, and finishing	Feedback, weighting, prototype
Partners	PEMDA, Industry, users	Industry, users	Industry, users	PEMDA, Industry, users
Location	Class, field	Class, studio, industrial workshop	Class, studio, industrial workshop	Class and studio
Time 16 weeks	7 weeks	2 weeks	5 weeks	2 weeks

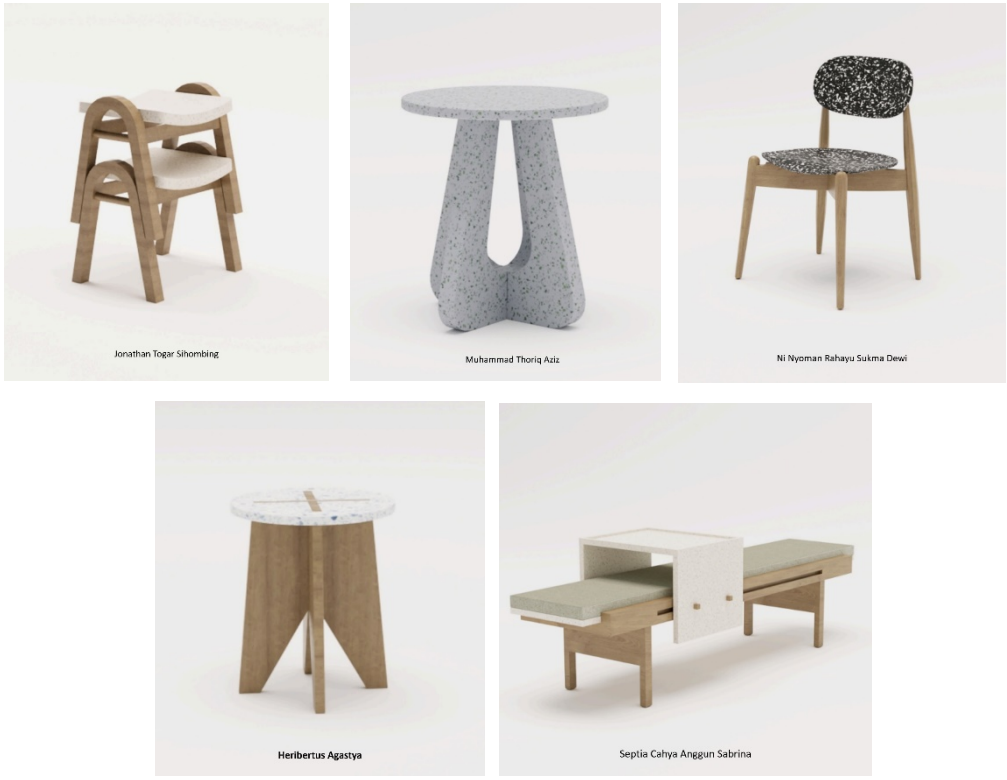

Figure 3. Five Designs of Green Reusable Furniture for Urban Young Family Homes by PSDI Students of FSRD ISI Yogyakarta.
[Source: PSDI Research Team, 2024]

Figure 4. Prototype furniture made from repurposed green materials produced by the industry PT. Inamas Sintetis Teknologi.
[Source: PSDI Research Team, 2024]

At the top is a table containing the design steps, including the research and development of the shape idea. The table details the activities undertaken at each stage, the working methods applied, the partners involved, and the location and time of implementation. Each step in the design process is explained in detail, providing clear guidance from start to finish. In addition, the table also includes collaborations with external partners to support the success of each stage. Below the table, the five furniture designs produced by the students in this project are listed, demonstrating their creativity and ability to create innovative pieces.

In conducting this applied research activity, students accompanied by lecturers worked with stakeholders, namely PEMDA, in this case, TPS3R, visiting this location to find out the amount of waste, types of waste, and how TPS3R manages the waste that has been collected at the place. Furthermore, this team visited the selected green material industry, PT. Inamas Sintetis Teknologi. Here, students observe how inorganic waste that has been collected is processed, starting from chopping and heating the material so that it becomes plastic liquid and then printed according to the desired mold model. In addition to material processing industry observations, students conducted online interviews. They sent Google forms to potential users of the design, namely young urban families living in Yogyakarta. The next stage is defining and developing the student team, working more in class and the studio, accompanied by the lecturer. However, there are certain times when we should ask the industry again.

The design process experienced by students this time became more complete, considering that in this project, they had the opportunity to look directly at the waste problems experienced by urban communities and waste managers. In addition, they also had the opportunity to visit an industry that recycles non-organic waste into new materials. These two experiences in the field are coupled with the experience of meeting product users they met in learning MK Residential Design in the previous semester. Entering the problem definition and design concept stage and at the ideation stage, students work a lot in class or the studio and consult with lecturers and the waste processing industry. This part is important because it discusses the possibilities of achieving the form and ensuring the strength of the construction. Finally, in the evaluation stage, several aspects can be tested; the aesthetic aspect is the part that can be tested well because it can be seen directly. While shape achievement and price aspects require experimentation and longer proving time, the interviews with the industry on 10 June 2024 showed that the resulting design could be mass-produced, and the product's durability is guaranteed (durable), but the price is still relatively high.

This research shows that by working in groups, interior design students have successfully conducted applied research and gained two main benefits. Firstly, they gained an in-depth understanding of the waste problem in Yogyakarta. Secondly, they were able to propose innovative solutions in the form of green repurposed furniture designs. This aligns with Ellen MacArthur's statement on the need for interior designers to be involved in the transition to a circular economy. This solution was realized by creating residential furniture for young families using recycled plastic waste materials. This work is a beautiful functional product [11], [13] and a manifestation of the concept of circular economy, where materials that are usually wasted can be reprocessed into something valuable and practical [3], [8]. With this approach, the students combined design creativity with environmental responsibility, creating relevant solutions to reduce waste and support future sustainability [1].

The effectiveness of students in conducting this action research can be achieved not only due to the good collaboration between students and lecturers but also because of support from various parties, such as TPS3R, the recycling materials industry, waste bank actors, and the community of design users. This collaboration allows students to engage directly with real-world issues and explore knowledge and skills from various sources, including experts outside the academic environment [14]. This differs from the learning approach in studios or classrooms that often focus solely on fictional design problems. In classroom studies, students tend to rely solely on the guidance of their lecturers and miss the opportunity to interact with field practitioners [15], [16]. Through action research, students can better understand the complexities of real-world problems and produce design solutions that are more relevant, applicable, and beneficial to society, thereby enhancing the overall learning experience.

The discussion above highlights the need to expand interior design students' understanding of the applications of circular economy and recovery and recycling business models. Although knowledge about recycling and material recovery is a good starting point, students must be equipped with various other green business models, such as rental-based models, resource sharing, or sustainable production [7]. By enriching their understanding of these various approaches, students can see how each model can be integrated into more innovative and environmentally friendly interior design. It is important to prepare them to face the challenges and opportunities of green transformation in the future [1], [5]. In addition, knowledge of various green business models will help students develop more comprehensive and flexible strategies in designing solutions that reduce environmental impact and create economic value. With this knowledge, they will be better prepared to apply sustainability principles holistically in their professional careers and contribute significantly to the green transformation in the interior design industry.

This statement highlights the project-based learning approach in interior design education, which focuses on direct observation and utilizing outputs from recovery and recycling business models. Through this course, students learn practically how the circular economy can be applied in the interior design industry, particularly in extending the product lifecycle and maximizing the utility of materials through recycling and recovery. This deeply explains how design can influence sustainability and resource efficiency. In addition, this approach can be compared to the product-as-a-service business model, where products are no longer sold for ownership but are provided as a continuous service [7]. For example, furniture that is rented or periodically updated, like what IKEA has already implemented in Switzerland with its furniture rental program or the option to buy used IKEA furniture with vouchers in Glasgow. This model emphasizes maintenance, repair, and rental, which should change students' perspectives on a product's meaning of 'use' and 'value.' By comparing these two business models, students can explore various strategies to achieve sustainability in interior design. They learned that there are many ways to reduce environmental impact, both through material recovery and services that extend product lifespan. This comparative approach helps students understand various green business models and develop more creative and environmentally responsible design solutions.

Integrating sustainable education into the interior design curriculum to support green transformation and demonstrate young designers' responsibility towards the environment is essential. One strategic step is to increase the number of project-based learning courses that hone technical skills and emphasize sustainability principles. Students can be encouraged to design creative solutions focusing on environmentally friendly consumption patterns and green business models. Thus, students will learn to practice circular economy in their designs to minimize waste through recycling and reusing materials. This approach is important for reducing the negative impact of the design sector on the environment, as this industry plays a significant role in resource use and waste production. In addition, by involving students in authentic projects related to sustainability, they can better understand the complexities of environmental issues and respond to the future industry's increasing focus on green solutions. This can strengthen the younger generation's commitment to environmental protection through more responsible design.

5. CONCLUSION

This research has shown how interior design students can internalize the principles of the circular economy, namely the principles of reduce, reuse, and recycle, thus presenting a mindset oriented towards sustainable environmental design. Future interior designers must understand this because they are responsible for designing spaces and products supporting environmental sustainability. By consistently applying circular economy principles, designers can help balance human well-being and environmental preservation.

The project-based learning model is suitable to be applied in a course that aims to understand the actual practice of circular economy in the design world. Through this approach, students learn theory and directly engage in practical projects that reflect real societal challenges and opportunities. Project-based learning also encourages students to think critically, collaborate, and find innovations in sustainability. As such, they are better equipped to apply these concepts in professional practice, contributing to developing more responsible and environmentally friendly designs.

In the future, the discipline of interior design and design in general can research and develop products based on the two elements of the circular economy: consumption patterns and business models. Consumption patterns focus on how people use products more efficiently, while business models lead to practices that support the recycling and reuse of materials.

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