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Product Life Sphere: a toolkit to support learning and teaching of product life cycle model

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Abstract

This study focuses on developing a new approach to teaching and learning of the product life cycle by proposing innovative design intervention, to enable students reviewing their design choices through environmental and social impact lenses. The physical model used as the design intervention, aims to promote circular thinking and emphasizes "tangible learning material" (Ræbild & Hasling, 2018) that holding the potential to expedite the learning process towards sustainable design education.

The primary inquiry of this paper responds to how might we re-contextualize new ways of interacting with and interpreting product life cycle? To address this gap, the author introduces the Product Life Sphere (PLS) model as a learning and teaching tool. The PLS is a three-dimensional model that offers a tangible representation of the various stages of the product life cycle. The model is structured in a way that each slice represents one stage in the cycle, and it prompts learners to take the sphere apart, connect or re-connect each slice, and physically engaging with the process, in which, it could stimulate discussions, collaboration, and lateral thinking (Chatterjee, 2010).

The study utilizes case study as a research method to frame the model, which involves an empirical inquiry into “a contemporary phenomenon within its real-world context” (Yin, 2014). To evaluate the effectiveness of the PLS model, a three-hour workshop was conducted with 48 first-year product design students from Foshan University. The workshop enabled students to explore, communicate, and reflect on the life cycle, and the engagement was evaluated by interacting with the PLS model. The data analysis includes observations, feedback, and three surveys (before the workshop, immediately after the workshop, and 150 days after the workshop). The process revealed that participants demonstrated a high level of engagement with the learning tool during the workshop, specifically, students were able to co-create two distinct folding methods to effectively re-present the sphere.

The research findings have significant implications for learning and teaching approaches in design education, representing the initial phase in a larger study that aims to facilitate a commitment towards sustainability among designers as "change agents" (Žalėnienė & Pereira, 2021) in their design practices.

Keywords: Product Life Cycle, Design Intervention, Learning and Teaching Tool, Responsible Design Practice, Environmentally and Socially Engaged Design Education

1. Introduction and context

The 2030 agenda of Sustainable Development Goals (SDGs) envision a world of peace and prosperity for people, society, and the environment (United Nations, 2015). As we approach the year 2030, the deadline for achieving the 17 SDGs goals, the urgency to enhance society's capacity to address complex problems has intensified. The report "Accelerating Education for the SDGs in Universities" (SDSN, 2020) states that universities play an imperative role in guiding students to contribute to SDGs goals through their learning and teaching. The concept of sustainability we understand it today, was first introduced during the UN Conferences in 1972 by the United Nations Environment Programme. Since then, sustainable development has become a crucial buzzword (Gamage et al., 2022) in higher education, in turn, universities have responsibility to consider sustainability when forming future professional knowledge (Žalėnienė & Pereira, 2021, p.100).

Sustainability is being increasingly recognized as an essential tenet in higher education, but the large-scale implementation of Higher Education for Sustainable Development (HESD) remains absent due to the significant drawbacks and limitations (Sundermann & Fischer, 2019). When locating HESD in mainland China, Choi et al. (2009) note that the increasing trend in academic publications related to sustainable development since 2003. Although several universities are offering sustainability related courses, the overall status of HESD remains in its preliminary or experimental stages.

There are currently 214 million students enrolled in higher education worldwide (UNESCO, 2017), and this presents a significant opportunity to influence the new generation with professional skills, a sustainable mindset, and responsive leadership. Higher education institutions and educators were responsible for engaging students with sustainable development by approaching innovative teaching and learning strategies (Longhurst et al., 2014).

The term of sustainability could refer to designing products for their entire life cycle while minimizing the impact on the environment, occupational health, and resource utilization (Alting & Jøgensen, 1993). Sustainability has been a topic in design education for several decades, especially in the realm of product design. Victor Papanek, who is famous for criticizing the lack of ecological and social (eco-social) responsibility in design practices. Papanek (1971) emphasizes that "design can and must become a way for young people to participate in changing society", it highlights the need for responsibility in design practices. Recent educators also believe that design students need to be cultivated with environmental and social responsibility (Ramirez, 2012; Zande, 2011). Therefore, design students should be encouraged and educated to address eco-social issues and work towards a design era that is both environmental and social responsibility.

The research proposes a learning and teaching tool as the core of this research, the intervention aims to promote sustainable education in higher education by generating life cycle thinking into a tangible model. The primary audience targeted to undergraduate design students, who could make responsible choices that benefit future society. The main research question addresses: “How might we re-contextualize the new ways of interacting and interpreting with product life cycle?” and follow by a sub-question: “How might the learners interact with the design intervention in the classroom context?” The learning and teaching tool, the Product Life Sphere model, challenges how students are being taught life cycle in design education. The model introduces new methods of thinking, doing, interacting, and communicating product life cycle concepts to learners. This research focuses on generating a new physical system of communicating product life cycles, to foster learners creating responsible and sustainable outcomes.

2. Methodology

This study conducts "an empirical enquiry" (Yin, 2014, p.16) to apply the Product Life Sphere model in a "real-life" (Creswell & Poth, 2016; Yin, 2009) context with in-depth and multi-perspective understanding (Crowe et al., 2011). The researcher employs case study as research methodology to frame the data collection process and utilizes the case within a classroom environment. Yin (2014) highlights that case study is a "linear but iterative process" (p.22) and points out that "case study research has a functional and legitimate role in doing evaluations" (p. 219). A workshop was conducted at art and design College, Foshan University (Foshan, China) in October 2021 to evaluate the impact of the learning and teaching intervention in the research.

Through the above approaches, the researcher was able to gain insights from the learning and teaching tool within a classroom context for addressing the research questions.

3. Learning and Teaching (L&T) Tool

The study employs a designer's skills, emphasizing the role of design thinking, design process, and design artefacts to create tangible learning material (Ræbild & Hasling, 2018), which generates changes and brings new ideas in how we teach students about design with a particular approach. L&T artefacts can serve as agents of change in education, highlighting the role of design in this field. Sadowska and Laffy (2013) investigate how design artefacts can aid students to learn complex content in the classroom environment. They suggest that tangible models provide students with a chance to embody their ideas, test them physically, and explore the emotional value of the design process through making. This interaction process helps students to consider issues from the individual perspective as a designer, as well as from the perspectives of different stakeholders.

The study developed a new systematic model named Product Life Sphere (PLS) functions as a learning and teaching intervention. The PLS is a tangible tool that can be utilized in the classroom for teaching sustainable design and discussing life cycle. The model exists in a three-dimensional each slice represents one stage in life cycle. It allows students to take it apart, interrogate the process, connect, or re-connect each slice together, and interact physically with all the processes locked together tightly. The prototype explores co-creation knowledge by enhancing the understanding of connection and circular thinking in sustainability education. In addition, a digital platform was developed (*https://crystalz1506.wixsite.com/theloopstudy*). The platform provides templates and instructions that show how the tools can be used by teachers and students. All the templates are available for download in pdf format and suggested to self-print on 200-300gsm paper.

The rationale behind designing the educational model was to re-contextualize how students are being taught in sustainability education and to suggest higher education a new way of thinking and teaching around the topic. The following section explains four characteristics that not only guided the design of Product Life Sphere to fit into the learning and teaching approaches, but also presented how these characteristics influenced PLS's design to be utilized in the classroom.

3-1 Multi-aspect

One of the significant problems with sustainable education is the common use of life cycle analysis for material understanding. A paper from Massachusetts Institute of Technology motivates design and engineering students to learn the design-for-environment process that enables progress toward sustainability by relating the life cycle thinking with a closed-loop system (Baeriswyl & Eppinger, 2011). The study provides a practical process for students to assess environmental impacts based on the detailed bill of materials, using only quantitative life cycle assessment tools. However, it has received critical attention that sustainability involves social and environmental context, such as considering issues from social equality, cultural heritage, animal rights, and more throughout the entire cycle. Similar issues are also occurring in Mainland China, during interviews and site visits in this study, evidence demonstrates that students usually create sustainable designs by reusing waste or end-of-life materials in their projects. However, it is important not to overlook the social aspect of sustainability in design practices. While incorporating sustainability into design practices is important, relying solely on life cycle analysis for material understanding is insufficient.

Therefore, the researcher has developed a learning and teaching tool to support students in considering each life cycle process in their practices. As presented in Figure 1, Template A includes common processes such as resources, extraction, transport, design, production, distribution, use and disposal; Template B leaves the stages blank for learners to fill out. The template offers flexibility for students at different levels to use in the learning environment.

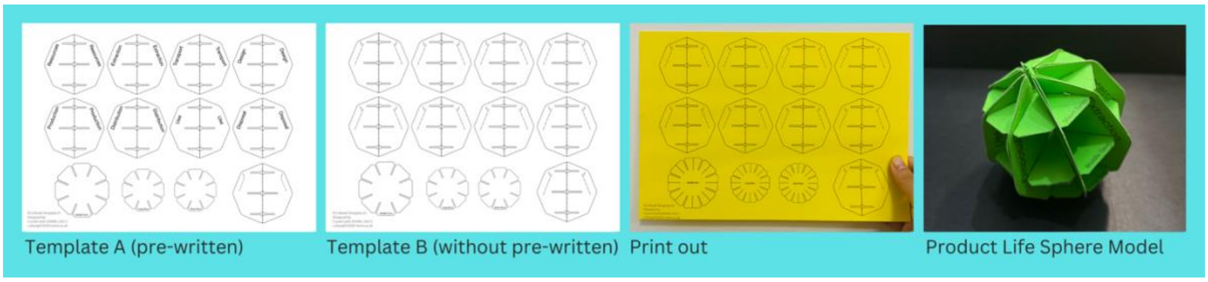

Figure 1 Product Life Sphere: template and model, Images: Author (2021)

3-2 Multi-dimensional

The significance of circularity has emerged as a response to contemporary unsustainable trends. It requires going beyond mainstream linear production models to support the efficient use and flow of resources. Circularity facilitates the transition from linear to closed loop process and helps identify the product life cycle archetype (Chioatto et al., 2020). Michael Braungart and William McDonough developed a set of design principles called Cradle to Cradle (C2C) in the 1990s. These principles suggest that products should be designed to ensure that all materials can be classified into cyclical systems (EPEA, 2021). C2C has spread the ideas of circular thinking and reinforced the presence of the life cycle in the last decades. However, it is challenging to provide an effective tool for students to understand each component's massive, complex inter-connectedness and inter-dependency.

To explore the visualization of circularity or the life cycle, consider a browser search as an example of receiving unknown knowledge in this decade. Searching for the keyword "Life cycle" on Google results in 1,240,000,000 findings (Google Search, 2021). However, the typical visual presentation of the life cycle is two-dimensional and circular with a flat-based. All the information is static, and it is impossible to transfer or add extra processes. The individual has no opportunity to explore and create a customized experience from different layers in the practices, such as the transportation process present before or after manufacturing.

Therefore, educators should reconsider the way of thinking and representing the life cycle. To address these issues, the Product Life Sphere Model (as shown in the last image of Figure 1) redefines circularity in multidimensional. With horizontal and vertical interlocks, it connects each process dynamically and enables a three-dimensional representation of the life cycle, which is more informative and insightful than two-dimensional graphics. As the design thinking process is "not linear but cyclical" (Luka, 2014), with each cycle building upon the previous one. The multidimensional characteristic of the model offers new opportunities for learning and exploring, as well as provides new interpretations of what needs to be taught in higher education.

3-3 Interactive pedagogy

Creating an interactive and dynamic relationship is an essential aspect of sustainability pedagogy (Burns et al., 2019). This evidence highlights the consequence of interaction in the teaching and learning life cycle, conversely, students who do not have enough engagement might be limited in adopting the knowledge. For students who will become future decision-makers, learning only the framework of the life cycle does not ensure progress toward achieving the Sustainable Development Goals (SDGs). Anderson (2015) demonstrates the notion of thinking-through-doing in the book "Designing for the Internet of Things". In the first chapter "Learning and Thinking with Things", Anderson illustrates that it is common in chess and Scrabble, players frequently rearrange tiles to see new possibilities. This process is called embodied cognition, in which thinking and doing are closely linked rather than one after another. Embodied learning engages our senses, creating more robust neural networks in the brain and we tend to use our environment to extend our thinking skills.

The PLS study provides analyses of experiences in working with objects and presents its relevance to learning outcomes. It strongly defines evidence of why the Product Life Sphere model encouraged interaction by making each slice (process) re-arrangeable and creating new sustainable possibilities for learners.

3-4 Co-creation

Burns et al. (2019) aim to provide empirical and theoretical evidence that a comprehensive outlook of themes can be created if individuals can bring their experience and perspective to the entire conversation. The PLS research approach has created an opportunity to involve different stakeholders in the process of creating solutions to complex issues.

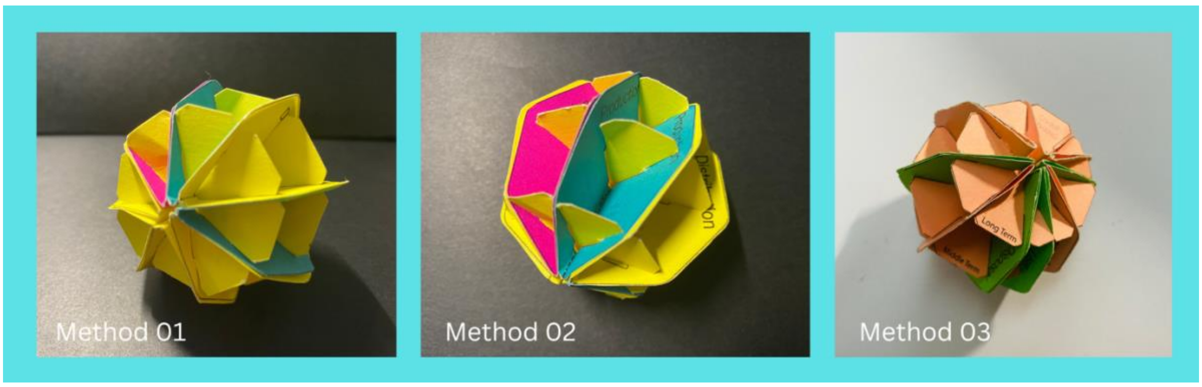

Figure 2 Product Life Sphere model: colour-coding approach and different folding methods, Photo: Author (2021)

The Product Life Sphere model incorporates the concept of co-creation by using colour-coding to display information and visualize relationships between stakeholders. This method enables participants to quickly identify and focus on specific elements of complexity. Furthermore, the model provides several ways to organize the slices. As shown in Figure 2, in folding method 01, colours are placed next to each other, with the sphere separated to avoid sharing colours. In method 02, the slices are opened and two colours are shared in one slot, representing the stakeholders sharing the same level of complexity. In method 03, additional proportions can be added to reflect the scale of the issues. Therefore, the cooperation process can be physically created, completed, and visualized.

To sum up, the design of learning and teaching tool proposes re-contextualizing how students interact and interpret with product life cycle. The L&T artefact brings the role of design practice, design thinking, and design artefacts into a broader design educational approach. Meanwhile, the section reflects four characteristics that influenced PLS's design and its application in the learning environment. When individuals start changing and refining the Sphere, the elements, and applying different colours to represent various things, the process involves individual impact while mobilizing and connecting with others to have an impact. Therefore, design as a discipline not only contributes to problem-solving but also effecting change.

4. The Product Life Sphere (PLS) Workshop

To evaluate the impact of the learning and teaching tool, a workshop took place in October 2021 at the Art and Design College of Foshan University in Guangdong Province, China. The workshop is designed to cultivate PLS model within the design major, using interactive teaching principles and pedagogy in the real classroom context. The workshop sits outside of students' assignment grading criteria and focuses on the learning process rather than the outcome. The three-hour workshop incorporated five stages (Figure 3) and involved the participation of 48 first-year product design students aged 18 to 19 years.

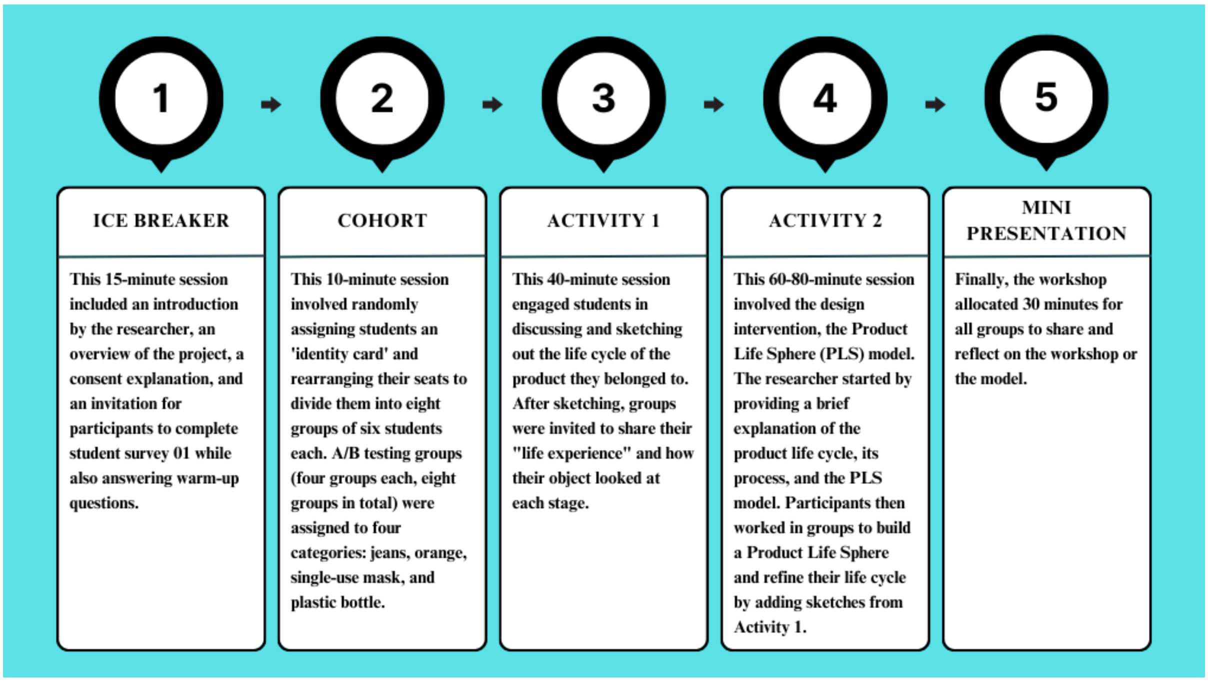

Figure 3 Workshop Stages

More specifically, the A/B testing divides participants into two big groups: “Group A” used the PLS model with 8 pre-written stages on the template, and “Group B” received a blank template without the pre-written process. The process aims to test the two versions of the Product Life Sphere template and observe how students reacted to them, what they learned from them, and whether the model would influence their understanding differently. In Activity 1, students sketched out their product's life cycle at the preliminary stages of the testing process without any instruction. The process evaluated students’ prior knowledge and visualized their understanding of product life cycle. In Activity 2, the co-created PLS model was used to highlight the impact of the model and communicates the knowledge of product life cycle.

During the workshop, students gained a comprehensive understanding of how each stage of design can impact the environment and society. Figure 4 illustrates examples of student engagement and outcomes from the workshops. Through this process, they developed the skills and knowledge to become eco-socially responsible designers by generating incremental impact across the life cycle.

Figure 4 Workshop Activities. Photo: Author (2021)

4-1 Evaluation of learning and teaching tool

Figure 5 evaluates that all groups have ability of assembling the sphere model, including disassembling each part from the template and building it into a sphere. However, when considering the order of processes, Group A generally followed the order shown in the template, whereas Group B displayed more creativity by naming the processes and adding extra stages to the slices. Furthermore, Group B usually spent more time than Group A analyzing the process and writing it down on the slices. Additionally, two groups in Group A provided feedback that they needed to translate the terms from English to Chinese to understand the model from a language perspective.

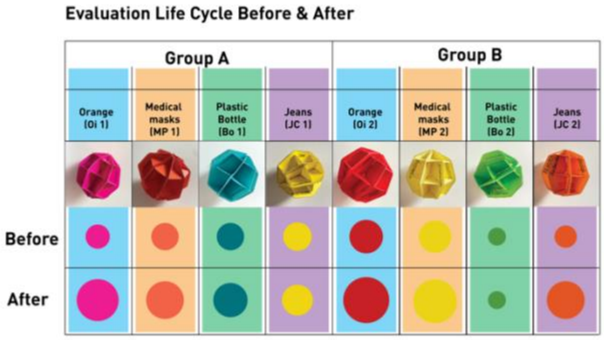

Figure 5 The results obtained from observation of the PLS creation process in eight groups, while the capacity of each dot represents the ability of completion. Source: Author (2021) - Left

Figure 6 Evaluation the Life Cycle Sketching before and after building the PLS model. Source: Author (2021) - Right

After building the PLS model, the groups added more processes to the life cycle on their previous sketches or presented them verbally. The mini-presentation showed that after creating the PLS model, they started considering additional processes such as transportation, labor health, salary, production, pollution, and the possibility of after-life use in their life cycle sketches. For example, Orange group 2 (Oi 2) considered that the feces of humans or animals can return to the land, nourish the soil, and improve the quality of oranges; Jean's group 2 (JC 2) described how developing nations produce jeans with chemical contamination which pollutes their water resources, then the jeans are exported back from developed countries for landfills or burning that could cause health problems for future generations. Those processes highlight the life cycle not only in the material aspect but also from society's perspective.

Figure 6 compares the life cycle drawing before and after building the design intervention. It is evidenced by considering the process completeness, circular thinking, and more possibilities in the new life cycle. However, it is recognized that the evaluation related to sketching, creating, or observing was subjective and could be susceptible to bias. Although the current study is based on a small sample of participants, the result found that controlled Group A, with pre-written stages, presented stable learning outcomes and slowly grew in transformation with less creativity. In comparison, Group B, with blank templates, tended to be more unexpected by showing rapid development by adding more related processes or not accomplishing the task ultimately.

4-2 Evaluation of learning and teaching outcome

Educators prove that self-report tools completed by students have been demonstrated to be valid indicators of their classroom environment (Waxman & Eash, 1983, p.321, as cited in Banning & Gam, 2020, p.7). This research uses three surveys as part of the larger data-collection process to evaluate learning and teaching outcome from students' responses. Survey 01 and 02 were conducted before and after the workshop (on the same day) to assess the impact of the PLS workshop and the design intervention. Data from Survey 03 was collected 150 days after the workshop from same group of students.

The demographic data in Survey 01 shows that the testing session consisted of 41.3% male and 58.7% female participants. The relatively balanced gender distribution should not significantly affect the results. Additionally, the data indicates that 98% (47/48 students) of the participants were from Guangdong, with only one student from Hubei. This finding states the limitation of the workshop, it focused on the Guangdong province and did not contain the differences in sustainability consciousness across various regions in Mainland China. It is worth noting that China has unbalanced economic development across its provinces with different levels of sustainability consciousness. For instance, the eastern part of China is relatively more developed than the west, especially the coastal cities, which have higher education levels (Choi et al., 2009). The analysis cannot represent the average level of understanding of the design outcome in Mainland China.

Besides background information, Survey 01 primarily aimed to assess the student's prior knowledge and understanding of sustainability, product life cycle, and Sustainability Development Goals (SDGs). Results show that 66.7% of the students had heard of sustainability before and had a basic understanding of it. However, approximately 30% of the students had no prior knowledge of the product life cycle and SDGs, and 40% had heard of them but were unsure of what they meant. These findings suggest that the students had limited familiarity with these concepts and terminologies before the workshop.

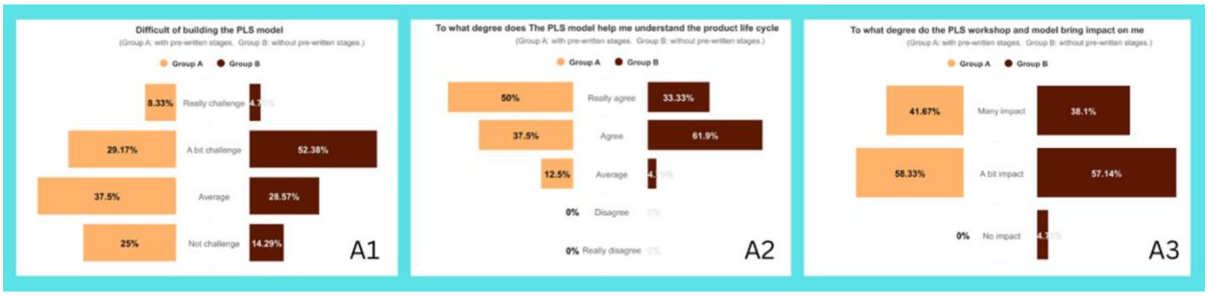

Figure 7 A/B Testing Group (Survey 2). Source: Author (2021)

In Survey 2, although Figure 7 (A1) presents the student's responses to the level of challenge in building the PLS model, there is no clear evidence showing that either pre-written stages (Template A) or none pre-written stages (Template B) are more difficult than the other. However, Survey 02 also indicates that 9 out of 10 students agree that the Product Life Sphere helps them better understand the product life cycle (PLC) and its significance to society and environment. When comparing data from Group A and Group B, Figure 7 (A2) appears that 50% of students in Group A and 33.33% of students in Group B strongly agree that PLS helps them understand the PLC, while none of the students disagree.

Data in Figure 8 (C2) displays that 97.78% of students believe the session and PLS model have impacts on them. While there is no considerable difference between Group A and B, both Template A (pre-written) and Template B (without pre-written) can impact students through different degrees (A3).

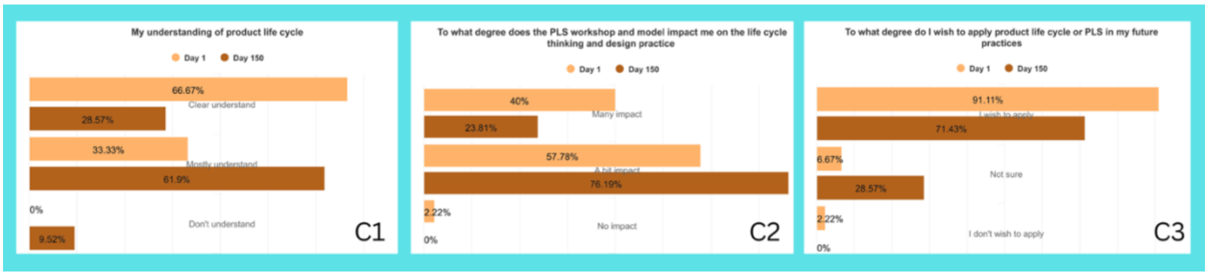

Figure 8 Comparison of day 1 (Survey 2) and day 150 (Survey 3). Source: Author (2021)

In response to Survey 02, 66.67% of the 48 students who completed the workshop indicated that they understood the content of the product life cycle clearly. The rest of the students primarily understood the content. However, Survey 03 (C1), conducted 150 days after the workshop, only 28.57% of participants thought they fully understood the knowledge, 61.9% evaluated themselves as mostly understanding the knowledge, and 9.52% of students reported that they did not understand the content. The data suggests that understanding of product life cycle knowledge could be influenced by time. Moreover, there is a slowly decreasing number of students who are willing to apply product life cycles in their future practices, as shown in Figure 8 (C3). On day 1, 91.11% of participants claimed that they wished to apply what they had learned to their future design practices. In comparison, on day 150, 71.43% of students were still willing to apply the principles.

A study by Seatter and Ceulemans (2017) emphasizes that when there is a change in beliefs, future action or transformation becomes evident, especially for the learner. More importantly, data from Survey 3 supports the statement that 47.62% of students tried to obtain more information from extra resources about the product life cycle after the workshop. To sum up, the survey results recognize that the L&T tool and workshop can reveal more incremental impacts on students that lead to a shift and subsequent change.

5. Discussion: The findings

The activity in the workshop engages students in discussing the given topic, cutting the template, analyzing the process and assembling the sphere, which aligns with cognitive, affective and psychomotor domains. The study (Sipos et al., 2008)) suggests that incorporating head (cognitive domain), hands (psychomotor domain) and hearts (affective domain) is crucial in developing sustainability competencies among learners and serves as an essential driver for change. However, previous studies have rarely integrated head, hands, and hearts into tangible sphere models in life cycle teaching under Chinese context. Thus, this study addresses the gap by designing the PLS model and evaluating its efficacy.

Numerous studies have emphasized the essential opportunities of sharing learning experiences in the classroom, which involve discussing and learning together as a group. Shared experience has been identified as a necessary component of sustainability education, as it connects course themes and fosters student’s relationships with each other (Burns et al., 2019). In the PLS workshop, 48 students were divided into eight groups, enabling them to engage in peer-to-peer learning, collaborate, sketch, and build the Sphere model. Working in groups not only enhances collaboration and communication skills but also develops circular thinking, which is essential for responsible and creative problem-solving in the future. However, the advantages of group activity depend on several factors, such as group size, individual characteristics and capacity. In addition, evaluating each student's learning outcome in a group setting is challenging as imbalances in contribution are common. For example, students with introverted thinking might not get the chance to express their ideas or participate in building the sphere due to the group size. Therefore, it is recommended to scale down the group size to three or four students in the future testing process.

6. Conclusions

The project examines the issues through the pedagogical lens by using design practice to improve pedagogy, defining the situation as a design problem instead of a teaching problem. The project states the idea that not only teachers should improve teaching but encourage educators using designer mindset to reinforce design education. The project utilizes design practice to create a learning and teaching tool that opens new ways of thinking, doing, and communicating life cycle with students. The researcher has elaborated on the rationales by designing the artefact, Product Life Sphere, which developed new approaches to interacting and interpreting product life cycles in sustainability education. The colour-coding and folding techniques employed in the Product Life Sphere model provide practical methods for visualizing complex relationships and stakeholder collaboration. The model highlights the importance of inclusive participation and the integration of diverse perspectives and experiences, thereby offering a comprehensive approach to sustainability.

The impact of learning and teaching intervention has been evaluated through the PLS workshop. On day 1, over 97% of participants reported a significant impact from the session and 91% expressed a desire to apply the PLS model to their practice. After 150 days, over 70% of students remained willing to apply the learning in their practices, and nearly 50% of participants sought additional resources to learn more about the life cycle after the workshop. These results demonstrate that design interventions and workshops have the potential to facilitate incremental impacts on students that lead to transformative shifts and subsequent changes.

The paper offers a set of approaches that integrate design practice, design process and design artefact (learning and teaching tools) to generate impactful learning experiences for students understanding climate action and social justice. The study re-contextualizes design, as a field of knowledge, has the potential to inspire action and foster potential change in the context of sustainability. As designers, we often underestimate the impact that a design mindset can bring about small but significant shifts in our practices. However, design as a discipline, the change can be gradual, and shifts in the learning process are invaluable. Placing design practice as a way of pedagogy is where design can lead to responsible action and create space for influence.

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