Collaborative and Iterative Business Design Research

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***Abstract*—This study focuses on the innovation of sustainable circular business models for enterprises, addressing the low implementation rate and the insufficiency of design thinking in its application, especially in terms of time efficiency and limitations in digital environments. To this end, the study employs Action Design Research (ADR) methodology, integrating the strengths of design science research and action research, to develop a framework named "Circular Sprint." Through multiple iterations of development and refinement, combining literature review, expert feedback, and data from six workshops, a tool for developing circular business models suitable for digital and efficient environments was ultimately formed. The experimental part compares the experimental group with the control group, using a combination of quantitative and qualitative data analysis methods to comprehensively evaluate the effectiveness of the framework. The results show that the "Circular Sprint" framework significantly enhances the performance of teams in developing circular business models, particularly in integrating multiple stakeholders, incorporating sustainability, and time efficiency, with the experimental group outperforming the control group. Moreover, the activities within the framework effectively support innovators in maintaining efficiency and creativity in time-limited digital collaborative environments. The contribution of this study lies in developing an operable tool adapted to digital environments, providing support for enterprises to innovate in circular business models in highly dynamic settings. By integrating design thinking with circular economy concepts and iterative optimization, it not only enriches the theoretical framework of circular business model innovation but also offers practical guidelines for business practitioners, educators, and policymakers. It extends the application of design thinking at the business model level and provides new ideas for embedding sustainability and circularity, filling the gaps in existing literature.**

Keywords—Co-creation; Iteration; Circular Economy; Business Design; Design Thinking; Action Design Research; Sustainability

I. Introduction

A. Research Background

Amidst the urgent global demand for transitioning to a sustainable economic system, the circular economy (CE) has garnered significant attention as an effective pathway for promoting sustainable development (Rezk et al., 2024). However, the implementation of sustainable and circular business models has been slow in practice (Nemakhavhani et al., 2024). This phenomenon has sparked a demand for more sustainable innovation tools and comprehensive business model innovation frameworks, as the practical application of circular economy concepts and the provision of practical guidelines for enterprises face numerous complex challenges (Mubarik et al., 2024).

Design thinking (DT), as an innovative problem-solving approach, holds potential in supporting processes oriented towards sustainable development, such as in the development of circular business models (CBM) (Rektor et al., 2024). In recent years, DT-based frameworks have gained popularity as they guide multidisciplinary teams through collaborative and iterative processes for understanding, ideation, and testing when tackling complex challenges (Peña et al., 2024). Although DT has been applied in the development of circular economy concepts, research and practice have mostly focused on product-level innovation or specific elements of circular business models, such as circular value propositions (Radjef et al., 2024). Moreover, while a few frameworks provide guidance for the entire process of circular business model innovation, they are still in the exploratory stage and require further research for refinement (Engez et al., 2024).

In the current highly dynamic business environment, enterprises face unprecedented challenges. Innovation at the business model level has become a key factor in gaining competitive advantage and even a matter of survival for businesses, with the time efficiency of the innovation process often determining its success or failure (Radjef et al., 2024). At the same time, online collaboration and digital transformation have become key organizational capabilities for businesses in recent years, with the COVID-19 pandemic accelerating this trend (Engez et al., 2024). Therefore, how to effectively guide the early development of circular business models through design thinking in a time-limited and digital environment has become an urgent issue to address (Rezk et al., 2024).

B. Research Questions and Methodologys

In light of the challenges mentioned above, this study aims to address the following key question: How can design thinking be applied in online collaborative environments to efficiently guide the early development of circular business models? (Cedergren et al, 2022). To answer this question, this study employs Action Design Research (ADR) methodology, which integrates Design Science Research (DSR) and Action Research (AR), with the aim of advancing scientific understanding and solving practical problems through the construction and evaluation of innovative artifacts (Lüftenegger et al, 2021).

Specifically, this study iteratively integrates literature on design thinking and circular business model innovation (CBMI), expert feedback, and data from 107 participants across six workshops, going through multiple stages to ultimately develop a process framework named "Circular Sprint" (Santa-Maria et al, 2022). This framework comprises twelve meticulously adjusted and combined activities that span seven distinct design thinking phases, aiming to provide practitioners with an effective approach for the early development of circular business models in a time-efficient and online environment (Chen et al., 2023).

To validate the effectiveness of the "Circular Sprint" framework, this study further designs and implements experiments, comparing the experimental group with the control group, and employs a combination of quantitative and qualitative data analysis methods to comprehensively assess the role and impact of the framework in guiding the process of circular business model innovation (Cronholm et al, 2024).

C. *Thesis Structure*

The structure of this paper is as follows: The second part elaborates on the relevant theoretical background, including the current state of research on design thinking, circular business model innovation, and their integration; The third part provides a detailed introduction to the Action Design Research methodology and process employed in the study; The fourth part presents the "Circular Sprint" framework and its activities, and evaluates its effectiveness through empirical results; The fifth part delves into key reflections on integrating sustainability and circularity within the design thinking process; The sixth part summarizes the main conclusions of the study, including theoretical and practical contributions, and points out the limitations of the research and future research directions.

II. THEORETICAL BACKGROUND

A. *Design Thinking*

Design thinking is an innovative and creative problem-solving approach that combines the sensitivity and methods of designers to integrate people's needs with technical feasibility and viable business strategies, transforming them into customer value and market opportunities. It has the potential to address complex or intractable problems, especially in situations with a high degree of ambiguity or uncertainty (Nazary et al., 2024).

The characteristics of design thinking include problem construction, user-centeredness, visualization, experimentation, and diversity, emphasizing observation, collaboration, rapid learning, rapid prototyping of concepts, and experimentation. It guides multidisciplinary teams in collaboration, uses abductive reasoning, integrates rationality with intuition, and adopts a Gestalt approach, viewing problems and their solutions as part of a larger system (Ayere et al., 2023).

Traditional design thinking frameworks are often based on three main iterative phases: exploration, ideation, and implementation/testing, with each phase involving the alternation of divergent and convergent thinking (Rosal et al., 2024). In the exploration phase, the aim is to understand the problem to be solved; the ideation phase generates potential solutions; the implementation/testing phase is based on prototyping and iteration (Rui et al., 2024). To span these phases, various tools and methods are commonly employed, such as ethnographic methods, user personas, journey maps, brainstorming, mind mapping, visualization, prototyping, and field experiments (Zen et al., 2024).

Despite the significant attention design thinking has received over the past decade, evolving from an innovation buzzword to a widely applied practice, initially applied to product design and later expanded to process and service innovation, and even attempted at the organizational strategy level, its application in the process of business model innovation remains relatively scarce (Khezriazar et al., 2024). To meet the demand for time efficiency in practical applications, methods such as the five-day "Design Sprint" developed by Google Ventures and the four-day version by the Design Sprint Academy have emerged in recent years.

B. *Circular Business Model Innovation*

The circular economy, as an alternative to the traditional linear economic model ("take-make-waste"), is dedicated to minimizing resource input, waste, emissions, and energy leaks by decelerating, closing, and narrowing material and energy loops, thereby maximizing the efficient use of products, components, and materials, and promoting sustainable development (Islam et al., 2024a). The key to transitioning to a circular economy lies in the development and promotion of business models based on circular economy strategies, namely circular business models (CBM) (Eriksson et al., 2024).

Circular business model innovation (CBMI) encompasses the creation of circular startups, the transformation of existing business models into circular models, the diversification of businesses in developing additional CBMs, and the identification and acquisition of external CBMs (Islam et al., 2024b). This innovation process is challenging and may involve changing key components of the business model and breaking through dominant business paradigms, as its inherent uncertainty widely recommends experimental methods for the process (Islam et al., 2024a).

Since the implementation of most CBMs requires collaboration across multiple stakeholders, it is necessary to view business models from a boundary-spanning perspective (Iyer-Raniga et al., 2024). An effective CBMI process requires businesses to adopt a lifecycle and systems thinking perspective to identify potential challenges and opportunities, while combining the application of retro-fitting and eco-design principles (Islam et al., 2024a).

It is noteworthy that an increase in circularity does not necessarily mean an improvement in sustainability, as trade-offs and rebound effects exist. The CBMI process still needs to follow sustainability criteria to ensure that the generated business models can effectively improve the sustainability of the system and to consider CBMI as a subset of sustainable business model innovation (SBMI) (Eriksson et al., 2024). In constructing the framework for this study, reference was made to the four guiding principles of SBMI proposed by Breuer et al. (2018) (i.e., sustainability orientation, expanded value creation, systems thinking, and stakeholder integration) and the four SBMI process-related criteria (i.e., reconstructing business model components, context-sensitive modeling, collaborative modeling, and managing impacts and outcomes) (Islam et al., 2024b).

To address the many challenges in the process of circular business model innovation, numerous tools have emerged. Traditional management literature and practitioner-oriented gray literature have proposed tools such as the widely used Business Model Canvas (Iyer-Raniga et al., 2024). In recent years, with the increasing emphasis on sustainability and the circular economy, a plethora of sustainable innovation tools supporting the SBMI or CBMI process have been proposed (Islam et al., 2024b). However, many scholars call for the development of methods that can view SBMI and CBMI as a continuous/integrated process, integrating CBMI, SBMI, and traditional BMI, and adjusting/customizing existing tools to fill research gaps. This study aims to address these issues, referring to the ten standards for CBMI tool development proposed by Bocken et al., including the tool's target orientation, rigor, iterativity, interdisciplinary knowledge integration, practicality, transparency, integration of sustainability objectives, ease of use, heuristics, and adaptability (Islam et al., 2024a).

C. *Application of Design Thinking in Circular Business Model Innovation*

Synthesizing the information on design thinking and circular business model innovation, design thinking appears to be a suitable approach to address the challenges of CBMI, as it helps guide multi-stakeholder collaboration and experimentation processes, gather insights across the entire lifecycle or system scope, and support the ideation, testing, and refinement based on circular economy concepts (Skaar et al., 2024). However, traditional design thinking processes may not consider three key aspects required for CBMI: first, solutions need to be formulated at the business model level, transcending product or service level innovation (Maselkowski et al., 2024); second, integrating circular economy strategies into new business models (Ijassi et al., 2024); and third, applying sustainable business model innovation principles to achieve positive sustainability outcomes.

Nevertheless, existing research has found that design thinking has some applicability in guiding sustainable innovation processes, such as Geissdoerfer et al.'s sustainable value ideation process, Baldassarre et al.'s sustainable value proposition design, and other related studies (Meslec et al., 2024). Buhl et al. and Kagan et al. also explored how design thinking can promote sustainable innovation, for example, by supporting positive sustainability outcomes through experimentation and visualization, integrating diverse perspectives through the participation of internal and external stakeholders, and suggesting the establishment of "sustainability checkpoints" in the process (Roundy et al., 2024).

This study methodologically draws on two previous proposals that combine design thinking with sustainable business model innovation/circualr business model innovation. Guldmann et al. proposed a design thinking framework for circular business model innovation, suggesting adjustments to the user-centered focus of design thinking to include a systems perspective, expanding the focus from users and inter-organizational collaboration to systems and value chain collaboration, which aligns with Kagan et al.'s criticism of design thinking (Ferrández et al., 2024). Guldmann also proposed adding an introductory phase to the design thinking process to better present circular economy principles and stimulate action, similar to what Bocken et al. did in their sustainable business model innovation value mapping tool (Glinik et al., 2024). Shapira et al. proposed an integrated sustainable design thinking process, which adds 20 additional components compared to the traditional design thinking process, guided by the Framework for Strategic Sustainable Development (FSSD). However, both studies are considered exploratory and require further refinement (Šilenskytė et al., 2024).

In addition, this study also considers two challenges in the adaptation of sustainably oriented design thinking that have not been fully explored. One is how to address the issue of the fast pace of industries and the limited time of stakeholders, which urgently requires the design of efficient and time-limited methods; the other is that previous research has not fully focused on how to adapt the process to digital collaborative environments, a need that has become increasingly urgent due to the COVID-19 pandemic.

The framework developed in this study aims to address the aforementioned limitations by intentionally considering the following aspects: embedding sustainability and circularity, targeting business model level outputs, covering the entire design thinking cycle, considering stakeholder time constraints, and adapting to online collaborative environments. Table 1 compares the selected design thinking-based methods, highlighting the characteristics and advantages of this study's framework.

D. *Interdisciplinary Integration from an Innovation Perspective*

From an innovation standpoint, the combination of design thinking and circular business model innovation reflects the trend of interdisciplinary integration (Ferrández et al., 2024). Design thinking originates from the field of design, emphasizing user experience, creativity, and iterative processes, while circular business model innovation is rooted in economics, management, and environmental sciences, focusing on resource recycling, sustainable development, and business model reconstruction (Ijassi et al., 2024). This interdisciplinary integration provides new ideas and methods for solving complex business and environmental issues (Ferrández et al., 2024).

In traditional business model innovation, there is often a focus on maximizing economic benefits while neglecting environmental and social factors. Circular business model innovation integrates the concept of sustainable development, requiring businesses to consider the finite nature of resources and the carrying capacity of the environment while pursuing economic growth (Ijassi et al., 2024). The introduction of design thinking provides a human-centered, innovation-driven approach to circular business model innovation, helping to break through the limitations of traditional thinking and inspire new business models and solutions (Ferrández et al., 2024).

For example, during the product design phase, applying design thinking can lead to a deeper understanding of user needs and behavioral habits, thereby designing products that are easier to recycle and reuse. At the same time, through the collaboration of interdisciplinary teams, integrating knowledge and skills from different fields such as material science, engineering, marketing, and environmental science, can better achieve product recycling and business model sustainability (Ijassi et al., 2024). This interdisciplinary integration not only helps promote the innovation of circular business models but also provides businesses with new differentiated advantages in market competition (Ferrández et al., 2024).

E. *Frontier Exploration under Digital Transformation*

With the rapid development of digital technology, businesses are facing unprecedented opportunities and challenges (Kolagar et al., 2024). In the context of circular business model innovation, digital transformation has become an important frontier area. This study considers how to adapt design thinking to the needs of digital collaborative environments when applied to circular business model innovation, which is an active exploration of this frontier trend (Perotti et al., 2024).

Digital technology provides powerful tools and platforms for circular business model innovation. For instance, big data analytics can help businesses better understand consumer needs and behavior patterns, thereby optimizing product design and business models (Véliz et al., 2024). Internet of Things (IoT) technology can enable real-time tracking and monitoring of products, improving resource efficiency and circularity (Urain Descarga et al., 2024). Online collaboration platforms facilitate teamwork across organizations and geographical locations, promoting knowledge sharing and the generation of innovation (Ishin et al., 2024).

However, digital transformation also brings new problems and challenges, such as data security, privacy protection, and the digital divide. In the design thinking process, these factors need to be fully considered to ensure that the application of digital technology truly promotes the innovation of circular business models instead of bringing new risks (Perotti et al., 2024). This study develops the "Circular Sprint" framework, which is adapted to online collaborative environments, providing valuable references and guidance for businesses in the process of digital transformation and circular business model innovation (Kolagar et al., 2024).

III. Research Methodology

A. *Research Design*

To address the question of how to apply design thinking in online collaborative environments to efficiently guide the early development of circular business models, this study selects Action Design Research (ADR) as its methodology. ADR combines Design Science Research (DSR) and Action Research (AR), two compatible research approaches aimed at advancing scientific understanding and solving practical problems.

DSR originates from the design science paradigm, aiming to develop prescriptive design knowledge by creating and evaluating innovative artifacts to solve a class of problems. AR, on the other hand, originates from natural and social sciences, generating practical and theoretical knowledge through iterative involvement of researchers and practitioners in a collaborative and participatory manner to address or interpret systemic issues.

In traditional DSR methods, problem identification precedes artifact development, followed by evaluation. However, this sequential approach may limit the organizational relevance of artifacts, as it overlooks how artifacts are (or should be) influenced by organizational contexts, an influence derived from the interaction between design and use. As a response to this limitation, ADR emerged as a "research method that generates prescriptive design knowledge by building and evaluating holistic artifacts in organizational contexts." Therefore, the ADR method is chosen for its ability to guide the development of organization-relevant artifacts, such as the "Circular Sprint" framework and its tools, while supporting knowledge generation (for a detailed ADR process, see Section 3.2).

The ADR method consists of four phases. The first phase is problem articulation, where perceived or anticipated problems are identified, initial research questions are formulated, and the theoretical and practical foundations and contributions are determined. The second phase includes iterative cycles of building artifacts, intervening in organizational contexts, and evaluating, resulting in the final design of the artifact. The third phase is reflection and learning, which runs parallel to and continuously with the first two phases, requiring conscious reflection on how the developed solutions generate applicable learning outcomes for broader problem categories. Finally, the fourth phase aims to formalize learning by abstracting insights into generalizable outcomes and sharing and disseminating results. Under the guidance of the ADR method, the alpha version of the "Circular Sprint" framework was tested and presented at an academic conference, and the reflections on the gamma version were showcased at another conference. This paper presents the final delta version of the framework, supplemented by the "Circular Sprint User Guide" in the additional materials.

B. *Research Process*

The ADR process of this study involves iterations between literature reviews, expert feedback, and a series of workshops, with 14 teams and 107 participants involved. The following describes the process in detail, Figure 1 presents an overview of the Build, Intervene, and Evaluate (BIE) phases in the ADR process, and Table 2 describes the workshops.

After clarifying the initial problem and research questions, a preliminary literature exploration was conducted to design the initial version of the framework. This process integrated four key literature streams: first, traditional design thinking frameworks; second, design sprint processes; third, best practices and tools selected from the field of traditional business model innovation; and fourth, innovative methods from sustainable business model innovation and circular business model innovation literature.

The draft framework was discussed by the authors of this paper and feedback was sought from six experts in the fields of innovation, design thinking, or circular economy. These experts were contacted through the authors' networks, and their feedback was used to design the alpha version of the "Circular Sprint" framework. This version was first piloted in an internal 3-hour workshop with seven scholars. Subsequently, at an academic conference, 39 sustainability professionals (including 30 researchers, 6 private sector practitioners, 2 public sector representatives, and 1 non-profit organization employee) formed five parallel groups to test the model for 6 hours, aiming to generate circular economy-based solutions for urban transportation in Graz, providing input for the development of the beta version.

Then, some activities of the framework were tested in two 3-hour workshops with master's students from Graz University of Technology in Austria and Hanze University of Applied Sciences in the Netherlands. In these two workshops, 29 and 20 students formed four and three parallel groups, respectively, to collaborate on generating business models to enhance the circularity and sustainability of four and three real case studies, and their feedback led to the refinement of the gamma version.

Subsequently, two of the most relevant and comprehensive interventions were conducted, each lasting three and a half days, covering seven design thinking phases and twelve consecutive activities. The first intervention supported a circular startup developing proprietary technology for producing bioplastics from waste in milk production to formulate its initial business model, with participants being a four-person interdisciplinary team (including CEO, intern, consultant, and mentor). The second intervention assisted a corporate collaboration project aiming to develop secondary use technology for electric vehicle batteries in conceptualizing alternative business model options, with participants being eight employees from five alliance organizations.

Finally, a "Circular Sprint" user guide for practitioners and its 12 activities were developed, detailing tools and application steps, and shared with 13 selected experts in the fields of innovation, design thinking, and circular economy for feedback. Inputs from startups and corporate workshops, as well as expert feedback, allowed us to refine the process framework and tools, resulting in the delta version of "Circular Sprint," which will be detailed in Section 4 (the final version of the "Circular Sprint User Guide" is available in the supplementary materials).

The structure of the workshops was adjusted according to each use case to accommodate the participants' availability, resulting in various activity combinations. Data was collected during the six workshops and expert feedback sessions through anonymous participant surveys, workshop documentation, and researcher/facilitator notes, providing relevant input for the improvement of the framework and tools throughout the BIE phase. Participant surveys used a 5-point Likert scale to solicit feedback on the perceived usefulness and ease of use of each activity, considered a determinant of user acceptance in the literature, supplemented by open-ended questions. Additionally, the final expert survey inquired about the degree of achievement of the "Circular Sprint" objectives (survey results are presented in Section 4.2). The first author of this study was the main facilitator for each workshop, assisted by other researchers who had previously been trained in applying the method. All workshops were conducted online, using video platforms (such as Zoom, MS Teams, or BigBlueButton) and the online visualization collaboration platform Miro, which provided template/canvas support for all activities. This research methodology aligns with the ten standards for CBMI tool development proposed by Bocken et al.

C. Experimental Design

To further validate the effectiveness of the "Circular Sprint" framework, this study designed an experimental section as follows:

1) Experimental Process

a) Problem articulation and framework design

Initial phase: After clarifying the research question, the initial version of the "Circular Sprint" framework is designed based on relevant literature and expert feedback. This phase includes conducting a preliminary literature review, collecting expert opinions, and developing and optimizing the preliminary version of the framework.

Iterative improvement: The framework is validated and iterated through internal and external workshops. Feedback from each workshop is collected and analyzed to improve the structure and activity combination of the framework.

b) Implementation of experimental workshops

Participants: 107 experts from business, academia, and the public sector participated in the experimental activities, which were conducted in multiple groups, each using the "Circular Sprint" framework in their respective experimental tasks.

Workshop activities: The workshop activities for each group included seven design thinking phases, namely inspiration, comprehension, definition, ideation, decision-making, prototyping, and testing. Each phase is accompanied by corresponding design activities, covering twelve collaborative tools to ensure that practitioners can flexibly apply the framework in different contexts.

c) Framework validation and evaluation

Data collection: After each workshop, participants' evaluations of the usefulness and ease of use of each activity are collected using a 5-point Likert scale for quantitative surveys, supplemented by open-ended questions to collect detailed feedback from participants.

Evaluation and optimization: The improved versions of the framework (including Alpha, Beta, Gamma, and Delta versions) are evaluated, and the "Circular Sprint" framework is optimized through continuous communication and feedback from experts, ultimately forming the Delta version for circular business model development in enterprises or startups.

2) Experimental Hypotheses

H1: Teams using the "Circular Sprint" framework will significantly outperform teams not using the framework in terms of efficiency in circular business model development.

H2: The "Circular Sprint" framework can increase teams' attention to sustainability and circularity during the design thinking process.

a) Experimental Group Design

Experimental group: Teams using the "Circular Sprint" framework, with a total of 8 teams, each consisting of 6-8 members from different industry backgrounds to ensure diversity.

Control group: Teams not using the "Circular Sprint" framework, using traditional design thinking methods, with a total of 8 teams, each consisting of 6-8 members.

b) Data Analysis

1. Quantitative Data Analysis

Data Collection Instrument: Data was collected utilizing a 5-point Likert scale, encompassing the following dimensions:

Framework Usability: Each team member provided a rating on the operability and ease of use of the "Iterative Sprint" framework.

Activity Effectiveness: Effectiveness ratings were assigned to each phase and activity, with a particular emphasis on assessing the activities' contributions to fostering teamwork and creative thinking.

Innovation Output Quality: Expert panels evaluated the business model prototypes submitted by each group, using criteria that included innovation, sustainability, and feasibility.

Data Analysis Methods: The methods comprised descriptive statistics, Analysis of Variance (ANOVA), and regression analysis. Descriptive statistics were employed to calculate the mean and standard deviation of various indicators; ANOVA was utilized to discern differences between the experimental and control groups regarding business model development efficiency and the quality of innovation outputs; regression analysis was conducted to analyze the impact of the framework's usability and the effectiveness of activities on the final outcomes.

2．Qualitative Data Analysis

Text Data: Post-experiment, responses to open-ended questions from participants were collected, with a particular focus on feedback regarding the activities within the "Iterative Sprint" framework.

Coding and Categorization: Open-source software (such as NVivo) was utilized to code the collected textual data, identifying primary themes and patterns. Specifically, this included feedback on the following issues:

a) Strengths and weaknesses of activities at each stage.

b) The impact of using the "Iterative Sprint" framework on team collaboration and innovative thinking.

c) By analyzing team collaboration records, identifying the mechanisms through which the framework influences team decision-making and idea generation.

c) Text Data

1．Quantitative Data Analysis

1.1.Quantitative Data Processing：

Exclusion of Incomplete and Anomalous Data Points: Data points that are incomplete or anomalous were removed, and Z-scores were utilized to identify and filter out potential extreme values.

Normalization of Ratings: Standardization techniques were applied to process ratings on usability, activity effectiveness, and other similar metrics to eliminate subjective biases among different raters.

1.2.Thematic Analysis:

By analyzing team collaboration records, identify the mechanisms by which the framework affects team decision-making and creative stimulation.

2．Data Integration and Graphical Presentation

2.1.Quantitative Data：

Utilizing Matplotlib to generate trend charts of scores across different activities for each group, illustrating the dynamic changes in scores for each group during various stages of the experiment. Scatter plots are employed to demonstrate the relationship between framework usability and the quality of innovation outputs, thereby clarifying the impact of framework usability on innovation outcomes.

2.2.Qualitative Data:

Create a thematic frequency analysis chart to display the occurrence frequency and distribution of main themes (such as "Collaboration Facilitation," "Time Efficiency," "Innovation Stimulation," etc.) across various groups in the experimental settings.

d) Experimental Results and Discussion

1．Quantitative Results:

The experimental group scored significantly higher than the control group in all dimensions (innovation scores, sustainability scores, etc.) ($p < 0.05$), supporting H1 and H2.

Usability is positively correlated with innovation output quality, indicating that the usability of the "Circular Sprint" framework has a positive impact on team innovation.

2．Qualitative Results:

Members of the experimental group generally believed that the "value exchange mapping"环节 was the most effective, helping the team understand the value exchange among stakeholders and facilitating the circular design of business models.

The control group reflected that the lack of systematic tools made it difficult to efficiently embed circular economy concepts into business models.

3．Results:

The experimental results indicate that the "Iterative Sprint" framework significantly enhances team performance in the cyclical development of business models through a series of structured activities, particularly in the integration of multiple stakeholders and the incorporation of sustainability, demonstrating its strengths. The systematic design of the framework allows teams to better utilize time and resources during the innovation process, effectively supporting the improvement of innovation quality.

CHART DESIGN AND STATISTICAL PRESENTATION.

Figure 1: Boxplot of Activity Effectiveness Scores for Each Group

This boxplot clearly shows the distribution of scores for experimental and control groups in activities at each design thinking stage. The box part represents the middle 50% range of the data (i.e., from the 25th percentile to the 75th percentile), and the line segment inside the box represents the median. The upper and lower whiskers (mustache lines) extend to the farthest data points within 1.5 times the interquartile range (IQR), and data points beyond this range are represented as separate points (may be outliers).

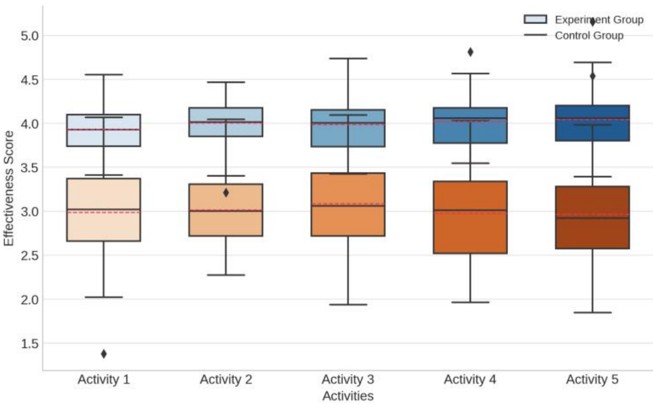

Fig. 1. Boxplot of Activity Effectiveness Scores for Each Group.

By observing the shape and coverage of the polygons, the relative strengths of the two groups in different dimensions can be clearly seen. The polygon of the experimental group extends further outward in several dimensions, particularly in innovation and sustainability. This highlights the comprehensive advantage of teams using the "Circular Sprint" framework in the quality of innovation outputs, with their business model prototypes performing more outstandingly across multiple key evaluation dimensions.

Figure 2: Radar Chart of Innovation Output Quality Scores for the Experimental and Control Groups

The radar chart originates from a central point, radiating outwards with multiple axes, each representing an evaluation dimension (such as innovation, feasibility, sustainability, etc.). In this study, the scores of the experimental and control groups on these dimensions are plotted on the radar chart, forming a polygonal area.

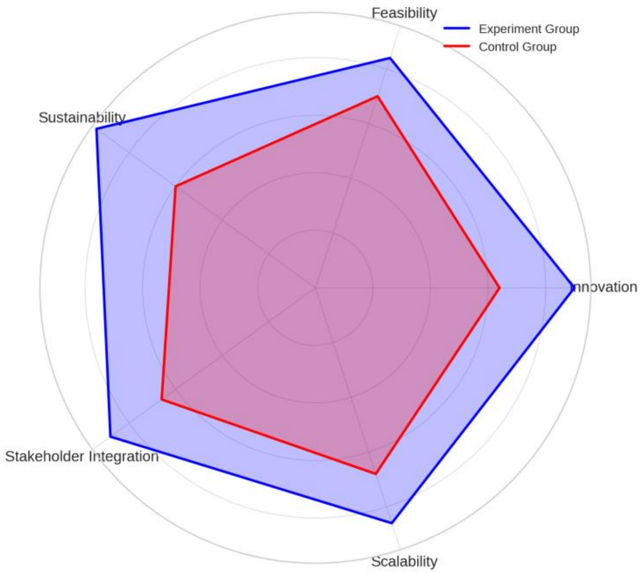

Fig. 2. Radar Chart of Innovation Output Quality Scores for the Experimental and Control Groups

By examining the shape and coverage area of the polygons, it is possible to discern the relative strengths of the two groups across different dimensions. The polygon representing the experimental group extends further outwards on multiple axes, particularly in the dimensions of innovation and sustainability. This highlights the comprehensive advantages of teams using the "Sprint Cycle" framework in terms of the quality of innovation output, with their business model prototypes demonstrating superior performance across several key evaluative dimensions.

Table 1: Regression Analysis Results for the Quality of Innovation Output

This table meticulously outlines the impact coefficients and levels of significance for variables such as framework usability and activity effectiveness on the quality of innovation output. The impact coefficients indicate the expected change in the dependent variable (innovation output quality) for each unit change in the independent variables (e.g., framework usability, activity effectiveness, etc.).

TABLE I. REGRESSION ANALYSIS RESULTS FOR THE QUALITY OF INNOVATION OUTPUT

Variable	Coefficient	Std. Error	t-Statistic	p-Value
Ease of Use	0.45	0.12	3.75	0.001
Activity Effectiveness	0.32	0.15	2.13	0.034
Collaboration Quality	0.29	0.13	2.23	0.028
Time Efficiency	0.41	0.1	4.1	0.0

The significance level (commonly denoted by the p-value) is utilized to determine whether the relationship between the independent variable and the dependent variable is statistically significant. For instance, if the p-value of a particular variable is less than 0.05, it indicates that at a 95% confidence level, the variable is considered to have a significant impact on the quality of innovation outputs. From the table, one can discern the impact coefficients and significance levels of variables such as framework usability and activity effectiveness, thereby ascertaining the importance of these factors in enhancing the quality of innovation outputs.

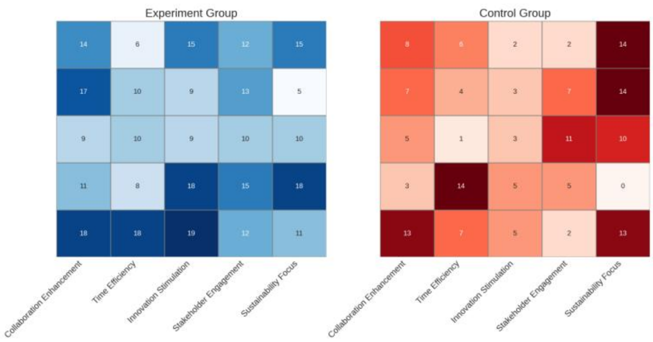

Fig. 3. Thematic Analysis Frequency Heatmap

The Thematic Analysis Frequency Heatmap represents the differences in the frequency of occurrence of major themes in qualitative data between the experimental and control groups using variations in color intensity. The darker the area, the higher the frequency of the theme's occurrence in the corresponding group.

For instance, regarding the theme "Collaboration Facilitation," if the area corresponding to the experimental group is darker than that of the control group, this visually indicates that teams using the "Circular Sprint" framework experienced a greater facilitation of teamwork during the experiment. This further demonstrates the framework's positive impact on team collaboration and innovation. In this way, the heatmap can quickly and intuitively display the patterns of influence of the framework on team behavior and cognition, providing strong visual support for the research findings.

Through the carefully designed presentation of charts and statistical analysis, the performance and effects of the "Circular Sprint" framework in the experiment can be presented more intuitively and comprehensively. This helps readers better understand the mechanism and value of the framework in the process of circular business model innovation. At the same time, these charts and analysis results also provide a solid data foundation for subsequent discussions and conclusions, highlighting the scientific and reliability of the research.

IV. Research Results

A. Developed Artifact: Circular Sprint Framework

The action design research methodology employed in this study has culminated in the creation of the "Circular Sprint" framework and its twelve associated tools. This is a conceptual process model based on design thinking that guides practitioners in efficiently developing circular business models (CBM) in an online environment. It is highly adaptable and can be applied to various scenarios, from supporting startups in initially conceiving and testing CBMs to assisting large enterprises in transitioning existing business models towards a circular economy or diversifying their development. With appropriate adjustments, the framework can also be applied to face-to-face or hybrid environments. The tools and activities provided are flexible and can be customized according to specific needs. While individual activities can be used separately for specific innovation purposes, the strength of the "Circular Sprint" lies in the sequential and iterative application of its activities.

The "Circular Sprint" framework consists of a preparatory phase before the workshop and seven distinct design thinking phases: Inspiration, Comprehension, Definition, Ideation, Decision-making, Prototyping, and Testing. The preparatory phase includes a problem framing session (recommended to be conducted at least two weeks before the main workshop sequence), supplemented by background research activities. The core of the framework begins with an introduction to the circular economy, followed by twelve collaborative activities. The recommended sequence of activities, their respective design thinking phases, and brief descriptions, as well as detailed step-by-step guides for practitioners and copies of exercise canvases supported by the online visualization collaboration platform Miro, are found in the supplementary materials. These activities were selected based on a review of relevant literature and customized according to the research objectives and the need for online execution. Their selection, combination, and details have been iteratively optimized through the aforementioned ADR process.

B. Artifact Evaluation: Feedback Survey Results

During the Build, Intervene, and Evaluate (BIE) cycles of the "Circular Sprint" framework, the framework and its activities were repeatedly assessed, providing a basis for improvement and evaluation of user acceptance. Qualitative content from feedback surveys and moderator notes supported modifications to various activities. For instance, improvements to the value chain mapping activity and its underlying principles are discussed. The following paragraphs summarize the most relevant quantitative feedback results, focusing on the overall evaluation of the framework.

The usefulness and ease of use of the activities were assessed using a 5-point Likert scale (ranging from "1 = Strongly Disagree" to "5 = Strongly Agree") to measure user acceptance. The overall usefulness of the activities received positive evaluations, with 89% of responses being "Agree" or "Strongly Agree," and an interpolated median (IM) of 4.36. The activities deemed most useful included "Hypothesis Mapping," "CBM Canvas," "Context Scanning," and "Value Exchange Mapping"; whereas "Customer Persona," "Lean BM Canvas," "Sustainability Scan," and "Vision Co-creation" were considered less useful.

Ease of use also received positive evaluations, with 90% of responses being "Agree" or "Strongly Agree," and an IM of 4.35 (see Figure 4). Activities such as "Conceiving with CBM Patterns," "Sustainability Scan," and "CBM Canvas" were rated as "easier to use"; whereas "How Might We?," "Lean BM Canvas," and "Test Cards" were perceived as more difficult to use.

Comparing feedback results from different workshops (see Table A1) indicates the importance of adjusting activity combinations based on specific use cases. For example, "Customer Persona," "Lean BM Canvas," and "Sustainability Scan" received lower usefulness ratings in corporate project cases (IMs of 2.0, 2.5, and 3.5, respectively) but higher ratings in startup cases (IMs of 4.5, 4.83, and 4.83, respectively). This may be because corporate projects focus on optimizing initial business model concepts for existing customer prospects, with a greater emphasis on profitability rather than sustainability; whereas startups with undefined customer groups in their business model concepts place more emphasis on sustainability issues.

As an indicator of overall satisfaction with the framework structure, the feedback survey also asked participants whether they agreed that "the activities are complementary, non-redundant, and optimally sequenced," which received a positive evaluation (IM = 4.68). Additionally, participants' views on whether "the virtual environment improved the results compared to face-to-face workshops" were generally neutral (IM = 3.09), but varied significantly (range = 4).

Finally, a feedback survey targeting nine experts was designed to assess the extent to which the "Circular Sprint" framework aligns with its primary objective—supporting the early development of circular business models—and its six expected key characteristics (see Table 1). The results indicate that the experts believe the framework substantially supports its main goal (IM = 4.4) and have provided positive evaluations for the six key features. The experts consider the most successfully implemented feature to be its adaptability to online environments, followed by the effective coverage of all stages of the design thinking process and the successful embedding of sustainability and circularity within the process. However, the experts perceive a lower degree of achievement in effectively generating outputs at the business model level and in terms of time efficiency, although there is significant variation in opinions on the latter (range = 3).

V. Discussion

A. Achieving Sustainable Innovation through Design Thinking

Prior to this study, a primary critique of traditional design thinking frameworks was that sustainability was only incorporated if intentionally chosen by the users (Firmansyah et al, 2024). Therefore, in the development process of the "Circular Sprint" framework, we recognized that for it to play a role in guiding sustainable innovation, sustainability must be foundational to the design thinking approach (Tu et al., 2024). This necessitates the addition of sustainability as a perspective to the three traditional innovation perspectives that guide the design thinking process: desirability, feasibility, and viability (Skaar et al, 2024).

Furthermore, we advocate that sustainability should permeate the entire innovation process, not just be reflected in the outcomes. In other words, sustainability considerations should not be seen as additional constraints but as opportunities within the innovation process. During the divergent thinking phase, sustainability can open up space for new ideas; during the convergent thinking phase, sustainability can be used to filter solutions (Meyer et al, 2024).

Embedding sustainability and circularity into the design thinking innovation process is challenging, but this study and previous experiences have proven it to be feasible (Carrard et al., 2024). The key difference between traditional design thinking methods and sustainability-oriented (or circular economy-oriented) methods is the shift from a user-centered focus to a more systemic/holistic perspective. The latter expands the focus from end customers to the system, from inter-organizational collaboration to value chain collaboration, aligning with the proposals of Guldmann et al. and Kagan et al., and also meeting Breuer et al.'s requirements for systems thinking and stakeholder integration in sustainable business model innovation (Firmansyah et al, 2024).

As mentioned earlier, the "Circular Sprint" method aims to meet the eight criteria for sustainable business model innovation proposed by Breuer et al. Table 9 demonstrates the contribution of each activity in achieving these criteria. For example, replacing the traditional "Customer Journey Map" with the "Value Chain Map" activity helps to understand from a systemic and lifecycle perspective, reflecting systems thinking (Tu et al., 2024). The "Vision Co-creation" exercise and its associated retro logic, the circular economy introduction session, the ideation activities based on CBM pattern cards, the sustainability-oriented criteria provided by the "Sustainability Scan" at key decision moments, and the modified version of the sustainability-oriented business model canvas used in the prototyping phase all support sustainability-oriented thinking (Skaar et al, 2024).

However, based on our experience with the "Circular Sprint" framework, there are two aspects that can significantly impact the level of sustainability and circularity of the outcomes. First, expert guidance may be necessary to break conventional thinking patterns and ensure that all proposed activities are correctly implemented (Carrard et al., 2024). Second, the composition of participants also affects the outcome characteristics, including sustainability/circularities as well as feasibility/viability/desirability. One of the advantages of design thinking is involving multidisciplinary and diverse teams, which helps incorporate various perspectives, which is usually recommended in sustainability-oriented processes. For example, the winning idea generated in the academic conference workshop was the most ambitious in terms of sustainability (possibly due to a higher proportion of sustainability researchers) but relatively low in economic feasibility; ideas from the corporate project workshop were higher in technical feasibility and economic feasibility but lower in sustainability potential; the best ideas from the startup workshop were more balanced between sustainability potential and economic/technical feasibility/social desirability, possibly attributed to the high diversity and commitment level of the participants (Meyer et al, 2024).

B. Application of Design Thinking in Business Model Innovation and Online Environments

Design thinking initially focused on product development, and although its application has expanded to various problem-solving contexts, its use in the process of business model innovation has only recently been explored. Our experience indicates that targeting business model level outputs in the design thinking innovation process is challenging but feasible (Braun et al, 2024). The formulation of the initial problem and the background knowledge of participants are crucial, as one workshop participant stated, "thinking in terms of business models is not an innate skill" (Monestier et al., 2024). There are trade-offs in adapting the design thinking process to achieve business model level outcomes, which need to be managed. We believe that pushing business model concepts too early may limit the potential for ideation and creativity, while using business model frameworks can quickly organize the best ideas into proposals that are feasible, viable, and desirable.

To address this dilemma, the "Circular Sprint" framework considers business model-related inputs in the introduction phase and then uses circular business model patterns to stimulate ideation activities. Additionally, to alleviate the burden on inexperienced participants, the framework includes a simplified version of the business model canvas and value exchange mapping activities before attempting to fill out a complete (circular) business model canvas.

The COVID-19 pandemic has forced us to adapt the design thinking process to digital environments, providing us with the opportunity to embed specific features in our artifacts and prompting us to explore the challenges of conducting such activities in online collaborative environments. Expert opinions indicate that our adaptation measures are effective, and user opinions show that the online version does not negatively impact the design thinking experience (Abdurrahman et al., 2024). Based on user comments and moderator discussions, we believe that the online collaboration format is particularly beneficial in supporting effective time management and achieving balanced contributions among participants. However, it somewhat limits overall user engagement and in-depth exploration of ideas. In addressing the challenges of the online environment, some methods proven particularly valuable include the use of silent brainstorming, idea clustering, and note voting techniques, combined with the use of visible online timers.

From the experimental results, the experimental group significantly outperformed the control group in terms of business model development efficiency and innovation output quality, further validating the effectiveness of the "Circular Sprint" framework in business model innovation. Regression analysis (see Table 1) revealed that the framework's usability and activity effectiveness have a positive impact on the quality of innovation outputs, indicating that a well-designed, easy-to-operate framework and activities can better guide teams in developing high-quality circular business models (Braun et al., 2024).

In terms of the online environment, although the experimental and control groups were generally neutral in their views on whether the "virtual environment improved the results compared to face-to-face workshops," the experimental group, using the "Circular Sprint" framework, was able to overcome the limitations of the online environment to some extent and achieve better innovation outcomes through specific online collaboration methods and tools, such as the application of the Miro platform. However, as participant feedback shows, there is still a need to further explore how to improve overall user engagement and in-depth exploration of ideas while maintaining the advantages of time management and balanced contributions.

C. Limitations of Interdisciplinary Research and Future Prospects

This study is exploratory in nature and has certain methodological limitations that restrict the generalizability of the findings (Abu-Bakar et al, 2024). Regarding the developed "Circular Sprint" framework, although we employed Action Design Research (ADR) methodology and conducted four iterative cycles in the Build, Intervene, and Evaluate (BIE) phase, it is uncertain whether a point of saturation in feedback has been reached (Stefanakis et al., 2024). Given the complexity of the framework, which includes 12 activities, future researchers can adjust and refine our proposals by exploring alternative activity combinations and further detailing the specifications of the activities (Deshpande et al., 2024). Additionally, future studies could examine the impact of different case backgrounds (such as industry, prior knowledge of participants, maturity of circular business model concepts, online versus offline environments, etc.) on the usefulness of the activities within the framework (Palmer-Abbs et al., 2024). We also welcome larger-scale testing of the framework's usefulness, ease of use, and industry adoption intentions (Katiyar et al., 2024).

Although the framework is presented linearly, design thinking is inherently iterative and cyclical. Therefore, future researchers could conduct longitudinal studies to gain a deeper understanding of the early development process of circular business models. Moreover, following business model concepts from ideation to effective market implementation through case studies would be of significant value (Stefanakis et al., 2024). Aspects of the framework that could be further developed include: (1) the level of external stakeholder engagement, such as by integrating open innovation practices; (2) considering the measurement (and management) of sustainability impacts, beyond potentially biased qualitative criteria; (3) focusing on the design-implementation gap in circular business model innovation, such as by enhancing the framework's iterative prototyping and testing phases (Abu-Bakar et al., 2024).

Regarding the feedback survey results, a limitation to acknowledge is that the positively phrased questions may inadvertently lead to response bias. Future studies are recommended to use more neutral wording to improve the accuracy of survey results (Katiyar et al., 2024).

Finally, it is worth noting that design thinking has faced some criticisms in both theory and practice, and future research will also need to consider these factors (Deshpande et al., 2024).

VI. Conclusion

The development of sustainable and circular business models is highly challenging, which has to some extent hindered their widespread application in the market. By integrating a design thinking-based framework with best practices from business model innovation, sustainable business model innovation, and circular business model innovation literature, we have developed, tested, and iteratively refined a process framework for guiding the early development of circular business models. This framework is characterized by its digitalization and time efficiency, encompassing twelve adjusted and combined exercises that span seven distinct design thinking phases.

This study addresses the growing demand from businesses for comprehensive operational guidance in the development process of circular business models. The proposed framework aligns with the call to view circular business model innovation as a holistic process, integrating sustainable business model innovation and traditional business model innovation methods, as well as customizing existing tools. This study strengthens previous approaches that apply design thinking to sustainability and provides empirical applications for the sustainable business model innovation criteria proposed by Breuer et al. and the circular business model innovation tool development checklist proposed by Bocken et al. Additionally, this study integrates and explores the principles of adapting design thinking to sustainable innovation theoretically proposed by Buhl et al. and applied in single-case studies by Kagan et al., successfully integrating sustainability and circular economy orientation into traditional innovation, design thinking, and business model management practices, supporting the integration and enhancement of these related fields. At the same time, this study expands the understanding of design thinking as a sustainable innovation process by integrating the four perspectives of desirability, feasibility, viability, and sustainability, contributing to theoretical development.

In terms of practice, we believe we have developed an actionable framework that can support the complex innovation process of developing, improving, transforming, or adapting circular economy-oriented business models. The research outcomes include a step-by-step guide with twelve exercises and their canvases, which can be used and adjusted by practitioners and innovators. Furthermore, this framework can also be utilized for educational purposes by students or companies, applied in teaching and training for circular economy thinking, circular business model development, and design thinking.

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