Developing a Speculative and Critical Design Learning Framework for Undergraduate Industrial Design Education

Abstract

Contemporary industrial design increasingly engages with complex social, ethical, and technological challenges that extend beyond conventional problem-solving approaches. In response to these challenges, Speculative and Critical Design (SCD) has emerged as an approach that emphasizes critical inquiry, reflection on assumptions, and engagement with alternative futures. Despite growing interest in SCD within design research, its integration into industrial design education remains limited by fragmented pedagogical practices and the lack of coherent educational frameworks. This study aims to develop a structured educational framework for integrating SCD into undergraduate industrial design education.

Following a Design-Based Research (DBR)-informed approach, this study reports the framework development phase of a broader iterative research process. The framework was developed through the synthesis of theoretical foundations, comparative curriculum analysis, and empirical investigation of speculative and critical design tools. The broader DBR process included subsequent implementation and evaluation cycles; however, this article focuses specifically on the development and conceptual structuring of the proposed educational framework.

The study identified key pedagogical requirements for SCD education and translated them into a sequenced learning structure. The outcome of this study is the Problem Reframing Framework for SCD Education, a five-phase educational model consisting of critical problem reframing, techno-ethical futures framing, scenario worldbuilding, speculative design intervention, and reflection. The framework is designed to guide students from questioning existing assumptions toward exploring alternative futures, constructing socio-technical scenarios, developing critical interventions, and reflecting on the broader implications of design decisions. The findings suggest that the proposed framework provides a coherent learning pathway for integrating critical thinking, futures literacy, systems awareness, ethical reasoning, and reflective practice within industrial design education. Furthermore, the framework offers a pedagogical structure that may support a shift from solution-oriented design education toward approaches that encourage critical inquiry and futures-oriented thinking among design students.

Keywords: Critical Design; Speculative Design; Industrial Design Education; Futures Literacy; Educational Framework

1. Introduction

Industrial design education has undergone profound changes in response to the evolving nature of design problems. Design challenges are no longer limited to functional optimization or the fulfillment of user needs (Rittel & Webber, 1973; Cross, 2006); rather, they are increasingly intertwined with complex social, ethical, and futures-oriented concerns (Buchanan, 1992; Meyer & Norman, 2020). Consequently, design is increasingly understood as an interdisciplinary activity concerned with complex systems rather than merely the development of functional products. Under such conditions, designers are expected to possess not only technical skills but also the ability to critically analyze problems, engage with uncertainty, and anticipate the long-term consequences of design decisions (Irwin, 2015; Escobar, 2018).

Critical design and speculative design are often discussed as distinct yet complementary approaches within contemporary design discourse. However, because contemporary design literature frequently brings these approaches together under the broader field of Speculative and Critical Design (SCD), the term is used throughout this article as an integrated educational concept. SCD has emerged in design discourse as an approach that emphasizes critical inquiry, the questioning of assumptions, and the exploration of alternative futures (Bleecker, 2009; DiSalvo, 2012; Dunne & Raby, 2013). Rather than treating design solely as a means of solving predefined problems, SCD positions it as a medium for generating discourse, revealing underlying values, and examining the socio-technological implications of possible futures (Auger, 2013; Malpass, 2017; Mitrović et al., 2021).

Despite its growing theoretical influence, the systematic integration of SCD into undergraduate industrial design education remains challenging. In many educational programs, critical and speculative concepts are introduced sporadically and are often confined to theoretical courses, with limited connection to studio-based design activities. This separation can prevent students from effectively translating critical thinking into design practice (Tonkinwise, 2011; Bardzell & Bardzell, 2013; Bayne & Ross, 2024). Moreover, empirical studies indicate that different SCD tools—including scenario-based games, futures-oriented techniques, and analytical frameworks—activate different cognitive and learning processes (Grace, 2014; Candy & Dunagan, 2017; Gil Farias et al., 2022). For example, tools based on ethical dilemmas can stimulate dialogue and value-oriented reflection, whereas analytical frameworks can support the structuring of reasoning, evaluation, and judgment (Facione, 2015; Brookfield, 2017; Ennis, 2018).

Nevertheless, these tools are commonly applied in isolation and without a coherent pedagogical structure. A major gap in the existing literature is therefore the absence of a framework capable of organizing complementary speculative, critical, analytical, and reflective tools within an integrated and sequential learning experience. Addressing this gap, the present study aims to develop a structured educational framework for integrating SCD into undergraduate industrial design education. In response to this gap, the study addresses the following question: How can speculative and critical design tools be organized into a structured learning framework for undergraduate industrial design education?

The development of the framework was informed by two complementary sources of empirical evidence: a comparative analysis of undergraduate industrial design curricula and an educational workshop involving undergraduate industrial design students. Together, these investigations provided insights into existing pedagogical gaps and the distinct learning functions of different speculative and critical design tools. Drawing on these insights and adopting a Design-Based Research approach, this article proposes the Problem Reframing Framework for Speculative and Critical Design Education as a structured pedagogical model for integrating critical inquiry, futures thinking, and reflective learning within undergraduate industrial design education.

2. Theoretical Background

Speculative and Critical Design as a Pedagogical Approach

Recent research on futures literacy in design education has emphasized the importance of developing students' capacity to question assumptions about the future and engage with multiple possible futures rather than relying on predictive approaches (Miller, 2018; Dziobczenski & Niemelä-Nyrhinen, 2026). Such perspectives align with SCD's emphasis on challenging dominant narratives and exploring alternative socio-technical possibilities.

SCD has been described as extending beyond the representation of alternative futures and serving as a means of critically interrogating assumptions about the present and the future. Through the use of design as a medium for storytelling and provocation, SCD creates opportunities to explore alternative socio-technical scenarios and stimulate discussion around contemporary societal challenges (Gil Farias et al., 2022; Østvold Ek et al., 2024). DiSalvo (2012) characterizes critical design as a form of adversarial design that intentionally creates situations of contestation and disruption. Within this perspective, designed artifacts function not as solutions but as vehicles for exposing hidden assumptions, values, and tensions. Critique is therefore not necessarily negative; rather, it can be understood as a productive distancing from established norms that creates opportunities for reflection and reconsideration (Malpass, 2017; Huard, 2022).

From an educational perspective, this shift repositions design from a process primarily concerned with solving problems to one focused on questioning and reframing them (Mitrović et al., 2021; Candy & Dunagan, 2017). Research suggests that futures-oriented activities can strengthen students' ability to engage with uncertainty and to imagine alternative possibilities. Consequently, SCD may be understood not only as a design approach but also as a pedagogical orientation that emphasizes ambiguity, dialogue, reflection, and critical inquiry (Candy & Dunagan, 2017). Within this framework, design is employed not to predict the future but to challenge assumed futures and explore alternative trajectories (Bayne & Ross, 2024).

Although speculative design and critical design originate from related but distinct traditions, they offer complementary educational potentials. Speculative design contributes the exploration of alternative futures through scenario construction, worldbuilding, and the materialization of possible socio-technical conditions. Critical design, in contrast, emphasizes questioning assumptions, revealing embedded values, and encouraging reflection on the social and ethical implications of design choices. While speculative approaches expand students' capacity to imagine alternative possibilities, critical approaches support the examination and evaluation of those possibilities. Therefore, their integration within SCD provides a pedagogical pathway that connects critical inquiry, futures exploration, speculative intervention, and reflective practice.

Recent scholarship has increasingly examined the pedagogical applications of speculative and critical approaches in design education. These studies indicate that speculative design activities can support students' engagement with uncertainty, alternative futures, and socio-technical challenges; however, many educational applications remain situated within individual workshops or specific techniques rather than articulated as comprehensive learning frameworks (Bayne & Ross, 2024; Bendor & Lupetti, 2025). Similarly, emerging research on futures literacy emphasizes the importance of enabling learners to question assumptions about the future and develop capacities for navigating uncertainty, suggesting a need for pedagogical structures that connect future-oriented exploration with critical reflection, ethical inquiry, and design action (Miller, 2018).

2.2 Critical Learning and Reflection in Design Education

Understanding SCD as an educational approach requires engagement with theories of critical learning and reflection. Brookfield (2017) conceptualizes critical learning as a process that emerges through exposure to diverse perspectives and reflective examination of experience. His model of critical reflection, structured around four lenses—self, peers, theoretical perspectives, and lived experience—provides a framework for examining and reconstructing learning experiences. Similarly, critical thinking models developed by Facione (2015) and Ennis (2018) emphasize analytical reasoning, evaluation, interpretation, and judgment. These capabilities are particularly relevant in design contexts characterized by ethical complexity, social uncertainty, and competing stakeholder perspectives (Buchanan, 1992; Irwin, 2015).

Within design education, these perspectives suggest that meaningful learning may not be fully captured through the production of design outcomes alone. Rather, learning emerges through reflection, dialogue, critique, and engagement with cognitive tensions that challenge existing assumptions (Facione, 2015; Brookfield, 2017; Ennis, 2018). Recent studies further indicate that critical thinking contributes significantly to students' capacity to navigate complex and ambiguous situations by supporting analysis, synthesis, and informed decision-making (Oo et al., 2024).

Futures literacy has been increasingly recognized as an important capability in design education, emphasizing the ability to identify assumptions underlying dominant futures and to explore multiple possible, probable, and preferable futures (Miller, 2018). Recent studies suggest that futures-oriented design education can help students move beyond prediction-oriented approaches toward critical engagement with uncertainty, values, and societal implications (Bayne & Ross, 2024). This understanding aligns with SCD's emphasis on challenging taken-for-granted assumptions and constructing alternative socio-technical possibilities, while highlighting the need for educational approaches that connect future imagination with critical reflection and design decision-making. However, assessing these forms of learning remains challenging because critical and speculative capabilities often involve changes in reasoning, reflection, and perspective-taking that extend beyond conventional outcome-based evaluation.

2.3 Critical Design Tools as Learning Interventions

A growing range of tools has been developed within the field of speculative and critical design, including scenario-based games, futures-oriented card systems, and analytical reflection frameworks. Rather than functioning solely as design methods, these tools can be understood as learning interventions that activate different cognitive processes such as imagination, dialogue, reflection, and analysis. Grace (2014) argues that game-based approaches promote engagement and collaborative discussion by creating interactive learning conditions that encourage cognitive participation. Similarly, futures-oriented methods have been shown to support imagination, scenario building, and exploration of alternative possibilities (Candy & Dunagan, 2017). In contrast, analytical frameworks grounded in critical thinking traditions, such as those developed by Facione and Ennis, support the structuring of reasoning and evaluation (Grace, 2014).

However, existing studies suggest that no single tool is likely to support the full range of learning processes associated with speculative and critical design education. Different tools tend to activate different dimensions of learning, with some emphasizing imagination and futures thinking, while others prioritize analysis, reflection, and argumentation (Candy & Dunagan, 2017). Consequently, meaningful learning is likely to depend on the purposeful combination of

complementary tools rather than reliance on any individual method. Furthermore, SCD can function as an integrative platform that connects multiple forms of knowledge and disciplinary perspectives, enabling students to examine complex problems from different viewpoints and engage with broader social and technological contexts (Mitrović et al., 2021; Wang, 2022).

Recent educational applications have also expanded toward design fiction and AI-related speculative practices. Design fiction approaches enable students to construct narratives, artifacts, and scenarios that make possible futures tangible and discussable. By transforming abstract technological and social possibilities into concrete narratives and artifacts, design fiction can support critical dialogue and reflection on the implications of emerging futures. Similarly, recent speculative AI workshops have demonstrated the potential of speculative approaches for developing critical awareness of technological futures and questioning assumptions embedded in emerging technologies (Kenny & Antle, 2024). These studies highlight the increasing relevance of SCD as a pedagogical approach for addressing contemporary socio-technical challenges and suggest the need for educational frameworks that integrate future imagination, critical inquiry, and reflective design practice.

2.4 Educational Gap and the Need for a Framework

Despite the growing presence of speculative and critical design within design education, research indicates that its implementation often remains fragmented. In many cases, SCD exists either as a theoretical discourse or as a collection of isolated tools and activities lacking pedagogical coherence (Tonkinwise, 2011; Bardzell & Bardzell, 2013; Bayne & Ross, 2024). This fragmentation may contribute to a gap between critical reflection and design practice. Students may become familiar with critical concepts at a theoretical level while lacking opportunities to integrate them meaningfully into design processes (Buchanan, 1992; Irwin, 2015). At the same time, previous studies suggest that different speculative and critical design tools play complementary roles in learning by supporting distinct forms of inquiry, imagination, ethical reasoning, and reflection (Candy & Dunagan, 2017; Mitrović et al., 2021; Gil Farias et al., 2022).

Although recent studies have expanded the pedagogical applications of speculative design, futures-oriented approaches, and design fiction, these contributions largely focus on specific activities, individual methods, or short-term educational interventions rather than comprehensive pedagogical architectures that guide students through a progressive learning pathway. In particular, limited attention has been given to how critical inquiry, futures exploration, speculative intervention, and reflective practice can be intentionally sequenced and connected within industrial design education. Therefore, the present study addresses this gap by developing a structured educational framework that moves SCD beyond the level of isolated tools and theoretical discourse toward an integrated learning process. Furthermore, despite increasing interest in speculative and futures-oriented design education, empirical investigations of structured educational frameworks and their assessment remain limited. Existing studies frequently report individual workshops or specific activities, while fewer studies examine how multiple speculative and critical learning mechanisms can be integrated into a coherent educational framework and evaluated systematically.

3.Methodology

This study is situated within a broader multi-phase Design-Based Research (DBR) process aimed at developing, implementing, and evaluating a structured educational framework for integrating SCD into undergraduate industrial design education. The present article focuses specifically on

the framework development cycle within this broader DBR process. The overall research involved iterative stages of theoretical investigation, empirical examination of existing SCD tools, framework development, implementation, and subsequent evaluation within the broader doctoral research project.

However, this manuscript concentrates on the transition from evidence generation to pedagogical framework construction. The framework development cycle reported in this article was informed by three complementary sources of evidence: theoretical foundations, comparative curriculum analysis, and an empirical educational workshop. Within this DBR trajectory, the development process was not treated as a linear synthesis activity; rather, it involved iterative movement between theoretical concepts, identified curricular gaps, and empirical insights generated through the exploratory workshop. These sources were synthesized to identify pedagogical requirements, refine the learning sequence, and construct the proposed five-phase framework. The subsequent implementation and evaluation cycles, which examined the educational application and further refinement of the framework, are beyond the scope of the present article.

In the first phase, a theoretical review was conducted to identify the conceptual and pedagogical foundations of speculative design, critical design, critical learning, reflective practice, and futures-oriented education. Particular attention was given to the roles of inquiry, assumption questioning, reflection, ethical reasoning, and engagement with alternative futures in design education (DiSalvo, 2012; Dunne & Raby, 2013; Auger, 2013; Brookfield, 2017; Mitrović et al., 2021). This phase provided the theoretical principles used to interpret the subsequent curriculum and workshop evidence.

The second phase drew on evidence generated through a comparative curriculum analysis. The analysis reviewed twenty-one undergraduate industrial design programs across North America, Europe, Asia, and Australia, including selected Iranian programs for contextual comparison. Program selection was based on the availability of curriculum documentation, the relevance of course content to critical, speculative, or futures-oriented design, institutional significance in design education, and geographical diversity. The analysis employed a matrix-based approach and examined learning outcomes, teaching and learning activities, studio integration, practical application, and the degree of constructive alignment among educational objectives, learning activities, and assessment practices (Miles & Huberman, 1994; Biggs, 1996; Biggs & Tang, 2011).

For the present study, the curriculum analysis was not reproduced as an independent set of results. Instead, its principal pedagogical implications were used as inputs for framework development. These implications included the fragmented inclusion of SCD-related content, limited connections between critical theory and studio practice, and a lack of clearly articulated learning sequences through which students could move from critical inquiry to applied design activity. The main criteria and identified pedagogical gaps derived from the curriculum analysis are summarized in Table 1.

Table 1. Curriculum analysis criteria and identified pedagogical gaps

Curriculum analysis criterion	Key observations
Learning outcomes	Limited explicit articulation of critical thinking, futures literacy, and speculative design competencies within undergraduate industrial design curricula
Course content	SCD-related concepts were generally introduced through individual courses or isolated topics rather than as an integrated educational pathway
Studio integration	Limited connection was observed between critical/speculative concepts and practical design activities
Learning activities	Few structured activities were identified for supporting scenario exploration, ethical inquiry, and reflective practice

Assessment approaches	Limited alignment between critical/speculative learning objectives and assessment strategies was observed

The third phase drew on evidence generated through an empirical educational workshop involving twenty-four undergraduate industrial design students. The workshop examined a range of speculative and critical design tools, including dilemma-based games, futures-oriented activities, and analytical and reflective frameworks. Examples included the Moral Machine, Things from the Future, Brookfield's critical reflection model, and Ennis's critical thinking framework. Data in the workshop study were collected through five-point Likert-scale questionnaires, structured observations, group discussions, and qualitative analysis of student-generated artifacts (Kolb, 1984; Brookfield, 2017). As with the curriculum analysis, the workshop was not presented as a standalone empirical evaluation in this article. Instead, its main educational findings were extracted and used as empirical inputs for framework development. These implications suggested that different tools may support distinct yet complementary learning processes, including ethical deliberation, futures-oriented imagination, structured reasoning, problem reframing, and critical reflection. The main educational contributions identified from the workshop activities are summarized in Table 2.

Table 2. Summary of workshop evidence and educational implications

Workshop activity/tool	Main observed contribution	Evidence from workshop
Moral Machine	Ethical reasoning and value-based analysis	Students engaged in discussions regarding competing values, stakeholder perspectives, and ethical tensions
Things from the Future	Futures imagination and scenario generation	Students developed alternative future scenarios and explored possible socio-technical consequences
Critical reflection frameworks	Structured reasoning and reflection	Students examined assumptions, evaluated perspectives, and reflected on design implications
Speculative design activities	Problem reframing and alternative intervention	Students moved from predefined problems toward broader social and technological questions

Qualitative data generated through workshop observations, group discussions, student reflections, and design artifacts were analyzed using an inductive thematic analysis approach. Initial codes were generated by identifying recurring patterns related to students' engagement with speculative and critical design processes. These codes were subsequently grouped into broader themes representing the learning mechanisms supported by the examined tools, including ethical reasoning, futures-oriented imagination, problem reframing, structured analysis, and reflective practice. The qualitative findings were triangulated with questionnaire responses and observational evidence to identify the complementary educational functions of different SCD tools.

In the fourth phase, insights from the theoretical review, curriculum analysis, and empirical workshop were synthesized to identify the design requirements of the proposed framework. This synthesis was guided by DBR principles, particularly the development of theoretically informed educational interventions through the integration of empirical evidence and iterative refinement. (Design-Based Research Collective, 2003; Wang & Hannafin, 2005; Reeves, 2006; Wang, 2022). Within this approach, the primary objective is not statistical generalization but the development of theoretically informed and contextually applicable educational solutions. To improve the methodological traceability of the framework development process, Table 3 summarizes the relationship between the evidence sources, the key empirical findings, the derived design requirements, and the corresponding framework phases.

Table 3. Relationship between evidence sources, identified requirements, and the proposed framework phases

Evidence source	Key findings	Derived design requirements	Corresponding framework phase(s)

Comparative analysis of 21 undergraduate industrial design curricula	SCD-related content appears fragmented and is often disconnected from studio practice	Need for an integrated and sequenced learning structure	Overall, five-phase framework
Curriculum analysis	Limited connection between critical concepts, futures thinking, and practical design activities	Connect critical inquiry with design action	Phase 1: Critical Problem Reframing; Phase 4: Speculative Intervention
Educational workshop with SCD tools	Different tools supported different learning processes, including ethical reasoning, imagination, analysis, and reflection	Combine complementary tools rather than relying on a single method	Integrated learning pathway across five phases
Workshop findings from futures-oriented activities	Supported scenario generation and exploration of alternative possibilities	Include futures-oriented exploration	Phase 2: Techno-Ethical Futures Framing; Phase 3: Scenario Worldbuilding
Workshop findings from analytical and reflective activities	Supported reasoning, evaluation, and reflection	Include structured reflection and evaluation	Phase 5: Reflection and Debate

Accordingly, the proposed framework is presented as a design-based pedagogical intervention derived from the synthesis of theoretical principles and previously generated empirical evidence. Its purpose is to organize SCD learning as a coherent process that connects critical problem framing, futures-oriented exploration, speculative intervention, and reflection. Figure 1 illustrates the overall development process and the relationship among the three sources that informed the framework.

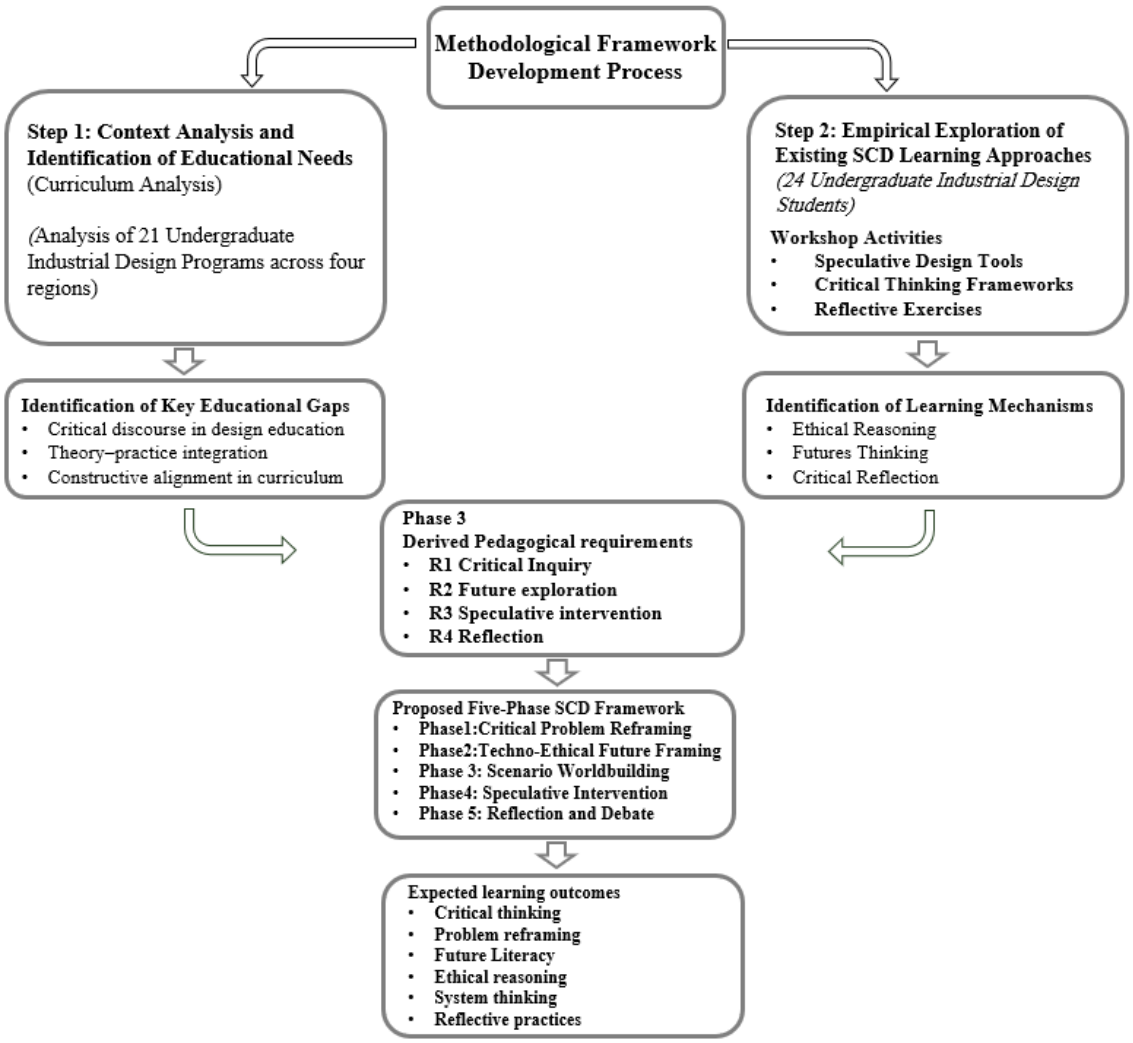

Figure 1. Evidence-informed development process of the proposed five-phase Speculative and Critical Design (SCD) educational framework.

Figure 1. Evidence-informed development process of the proposed five-phase Speculative and Critical Design (SCD) educational framework, illustrating the relationships among theoretical foundations, curriculum analysis, workshop evidence, derived pedagogical requirements, framework phases, and intended learning outcomes.

4. Findings and Design Requirements

The synthesis of curriculum and workshop evidence resulted in a set of findings that informed the development of the proposed framework. Through the synthesis of the theoretical foundations, curriculum analysis, and empirical workshop evidence, four design requirements were identified as guiding principles for the development of the proposed framework (Miles & Huberman, 1994; Braun & Clarke, 2006). These requirements functioned as analytical links between the evidence base of the study and the structural components of the final framework.

Integration of Complementary Learning Tools

The workshop evidence suggested that different speculative and critical design tools may support distinct cognitive and educational processes. While speculative games and futures-oriented activities primarily encouraged imagination, exploration, and futures thinking, analytical frameworks supported critical reasoning, evaluation, and reflective judgment. No single tool appeared sufficient to address the full range of learning dimensions associated with SCD education. Consequently, the proposed framework was required to support the purposeful integration of complementary tools and activities, enabling students to engage with multiple forms of inquiry, reflection, and speculation throughout the learning process.

Need for a Sequenced Learning Process

The curriculum analysis suggested a limited presence of coherent learning sequences for integrating speculative and critical design within industrial design education. In many cases, critical concepts were introduced as isolated topics rather than as interconnected stages within a developmental learning process. This finding suggested the need for a structured pedagogical sequence capable of guiding students from initial problem exploration toward critical reflection and futures-oriented design inquiry. In response, the proposed framework was organized as a progression of interconnected learning phases that support the gradual development of critical and speculative competencies.

Reflection as a Core Learning Mechanism

Both theoretical and empirical evidence pointed to the importance of reflection in supporting meaningful learning experiences. Workshop observations indicated that students developed deeper insights when they were encouraged to question their assumptions, reconsider alternative

viewpoints, and critically examine the implications of their design decisions. Reflection therefore emerged not as a final evaluative activity but as a central learning mechanism that should be embedded throughout the educational process. As a result, opportunities for both individual and collaborative reflection were incorporated across multiple stages of the framework.

Emphasis on Problem Reframing

A recurring theme across both the theoretical literature and the educational evidence was that conventional design education often places greater emphasis on solution generation than on the critical examination of the problem itself. In contrast, speculative and critical design approaches encourage students to question assumptions, expose underlying tensions, and explore alternative interpretations of design situations (DiSalvo, 2012; Dunne & Raby, 2013; Malpass, 2017). Accordingly, the proposed framework places particular emphasis on problem reframing rather than immediate solution generation. Rather than directing students toward the development of optimized design outcomes from the outset, the framework encourages them to critically examine the nature of the problem, investigate its social and ethical dimensions, and explore alternative futures before proposing design interventions. This requirement informed the early stages of the framework and contributed to the overall shift from solution-oriented learning toward critical and futures-oriented inquiry.

Pedagogical Roles of SCD Tools

To clarify how different approaches contributed to the structure of the framework, the reviewed tools were classified according to their dominant cognitive focus, pedagogical role, and expected learning output. Table 4 presents this pedagogical typology. The classification is not intended to rank the tools; rather, it demonstrates that each approach supports a different component of the learning process.

Table 4. Typology of Speculative and Critical Design Tools and Their Pedagogical Roles in the Learning Process. Source: Authors.

Source / Approach	Tool / Method Type	Cognitive Focus	Learning Role	Educational Output
Dunne & Raby (Speculative Design)	Conceptual Artifact Design	Futures Imagination, Social Critique	Challenging the Status Quo	Conceptual Artifacts
DiSalvo (Adversarial Design)	Critical and Tension-Based Scenarios	Socio-Political Awareness	Provoking Dialogue and Debate	Critical Situations / Dialogues
Design Fiction	Future Narrative Construction	Futures Thinking	Developing Alternative Scenarios	Narratives / Scenarios
Cultural Probes	Context Exploration Tools	Empathy, Contextual Understanding	Revealing Hidden Layers of Experience	Qualitative Insights
Moral Machine	Ethical Dilemma-Based Game	Ethical Reasoning	Confronting Difficult Choices	Value-Based Decision Making
Things from the Future	Futures Combination Cards	Creativity, Imagination	Rapid Idea Generation	Future Scenarios
The Future Backwards	Past–Future Analysis	Systems Thinking	Understanding Consequences	Scenario Maps
Brookfield	Critical Reflection Framework	Reflection	Examining Assumptions	Reflective Insights
Paul–Elder Framework	Structured Critical Thinking Framework	Logical Analysis	Structuring Reasoning	Analytical Frameworks
Facione	Critical Thinking Skills Framework	Critical Judgment	Informed Decision Making	Argument Analysis

As shown in Table 1, the reviewed approaches support different dimensions of learning, ranging from futures imagination and scenario construction to ethical reasoning, contextual interpretation, and critical reflection. No single tool appears sufficient to address all of these dimensions. This differentiation supports the need for a structured framework in which complementary tools can be combined according to their pedagogical functions (Candy & Dunagan, 2017).

From Findings to Framework Structure

The synthesis of curriculum and workshop evidence highlighted the need to organize complementary SCD tools within a coherent learning structure. While some tools primarily support imagination and futures thinking, others emphasize analysis, ethical reasoning, or reflection. However, these activities are often implemented independently, with limited pedagogical connections between them (Grace, 2014; Brookfield, 2017). This observation highlighted the need for an integrated educational structure capable of organizing complementary learning activities within a sequenced process (Wang & Hannafin, 2005). Such a structure should support students in moving from questioning assumptions and reframing design problems to exploring alternative futures, constructing socio-technical scenarios, developing speculative interventions, and engaging in critical reflection.

The proposed framework was developed in response to this need. Its five-phase structure translates the design requirements identified in the previous section into a coherent learning sequence (Figure 2). Each phase addresses a specific educational challenge and contributes to a broader process of critical inquiry, futures-oriented exploration, systems thinking, design intervention, and reflection. Rather than functioning as isolated activities, the phases are intended to operate as interconnected components of a structured learning experience.

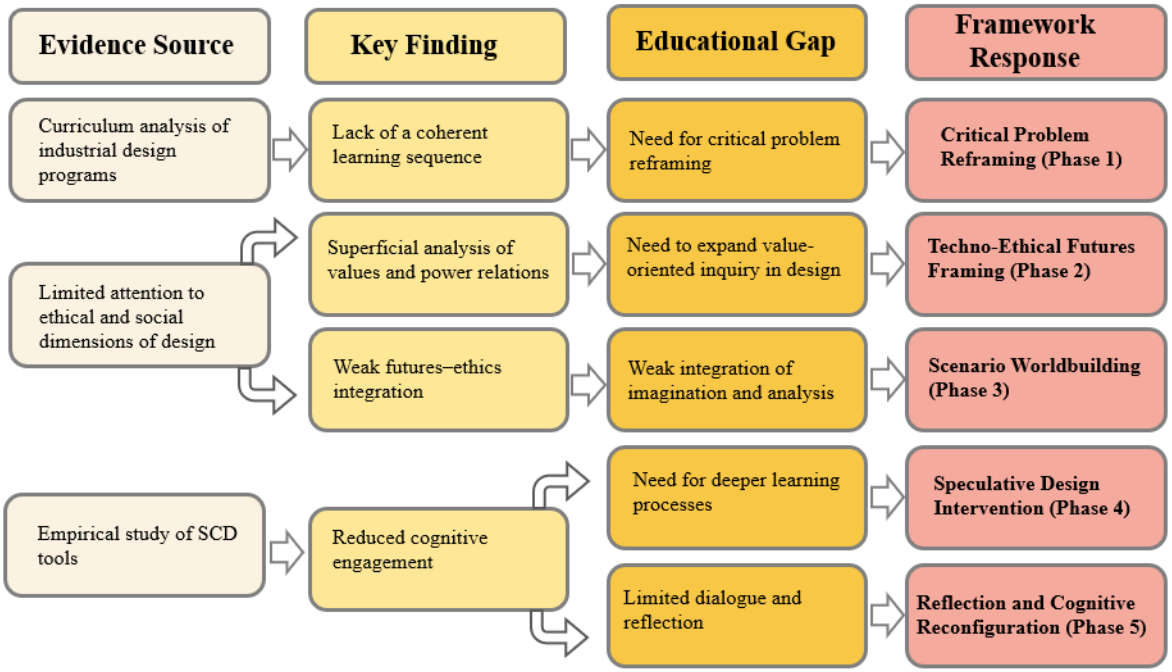

Figure 2. Translation of educational gaps and design requirements into the structure of the proposed framework. Source: Authors.

Figure 2 illustrates how the educational gaps identified through curriculum analysis and the learning patterns revealed through the workshop study informed the structure of the proposed

framework. Each phase was informed by a combination of theoretical insights and educational evidence identified during the synthesis process. The resulting framework therefore represents a systematic translation of theoretical foundations, curriculum findings, and empirical evidence into a coherent learning sequence for Speculative and Critical Design education.

5. The Problem Reframing Framework for Speculative and Critical Design Education

Based on the identified design requirements and the pedagogical roles of the reviewed tools, the Problem Reframing Framework for SCD Education was developed as a five-phase learning structure (Figure 3). The framework is intended to guide undergraduate industrial design students from the critical examination of an existing problem toward the construction of alternative futures, the development of speculative interventions, and reflective reconsideration of their assumptions and professional responsibilities.

The five phases are sequential but not strictly linear. Although each phase produces a defined learning output, students and educators may return to earlier stages when new tensions, assumptions, or implications emerge. This iterative structure reflects the logic of Design-Based Research and reflective learning, while preserving a clear pedagogical progression from inquiry to speculation, intervention, and cognitive reconfiguration (Wang & Hannafin, 2005; Reeves, 2006).

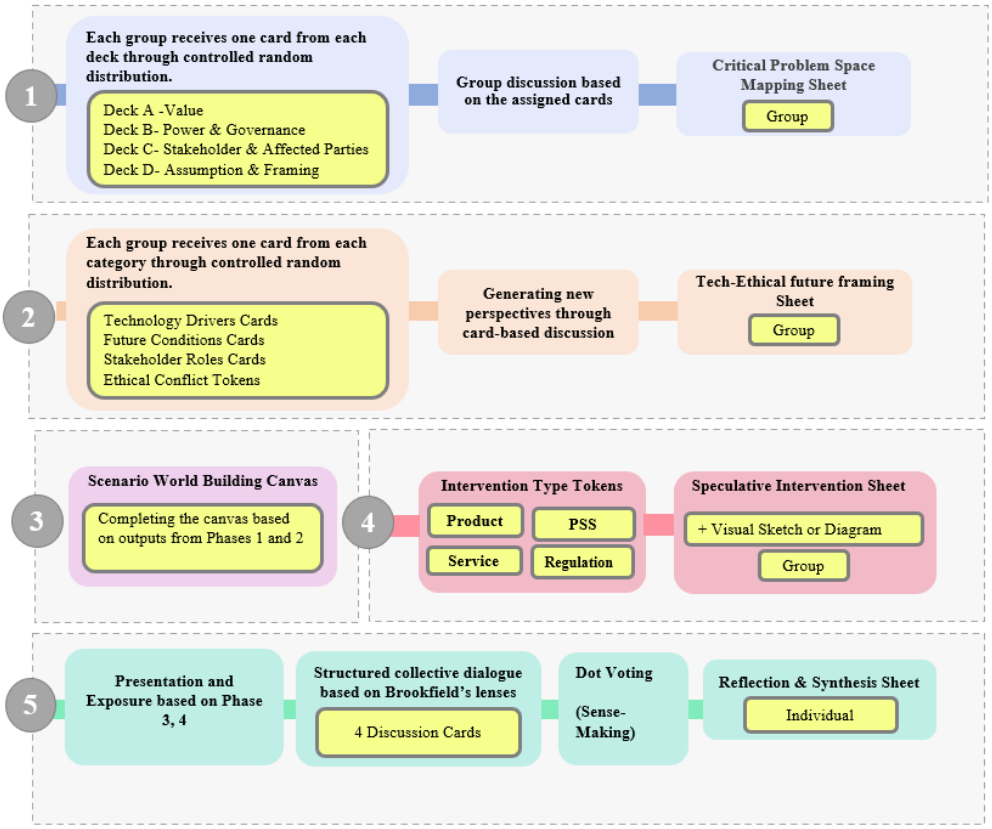

Figure 3. Five-phase structure of the proposed framework for Speculative and Critical Design education. Source: Authors.

The framework may be implemented as a standalone workshop, a short educational module, or as part of undergraduate industrial design studio courses. Each phase organizes analytical, futures-oriented, speculative, and reflective activities within a coherent learning process. The flexibility of the framework allows adaptation to different design themes and levels of educational complexity. To clarify its operational structure, Table 5 summarizes the educational objectives, core activities, and expected learning outputs associated with each phase.

Table 5. Summary of the Proposed Five-Phase Educational Framework. Source: Authors.

Phase	Educational Objective	Core Activity	Expected Output
Phase 1: Critical Problem Mapping	Identifying the problem, stakeholders, and underlying assumptions	Systems analysis, stakeholder mapping, critical inquiry	Problem map and key assumptions
Phase 2: Futures Framing	Developing futures thinking and identifying drivers of change	Trend analysis, drivers of change, and future conditions exploration	Initial future scenarios
Phase 3: Scenario Worldbuilding	Constructing alternative and plausible worlds	Development of socio-technical narratives and scenarios	Speculative scenario and future world description
Phase 4: Speculative Intervention	Developing critical design responses	Ideation and design of artifacts or interventions	Critical design concept or artifact
Phase 5: Reflection and Integration	Evaluating implications and supporting critical reflection	Group discussion, individual reflection, and implication analysis	Critical, ethical, and futures-oriented insights

As summarized in Table 2, the framework is intended to guide students through a progression from critical examination of existing conditions toward futures exploration, speculative intervention, and reflective learning. The combination of clearly defined objectives, activities, and outputs provides a structure that may support implementation across a range of educational formats, including workshops, studio courses, and short-term learning modules.

Phase 1: Critical Problem Reframing

Purpose. This phase focuses on challenging students' initial understanding of the design problem by revealing the assumptions, value structures, and power relations embedded within it. Rather than treating the problem as a fixed and predefined entity, students are encouraged to critically examine how the problem is framed and whose perspectives and interests are represented or overlooked.

Activities. Students work with analytical cards addressing four dimensions: values, stakeholders, assumptions, and power and governance. Through guided discussion and mapping exercises, they construct a Critical Problem-Space Map that helps identify hidden tensions, competing interests, and alternative interpretations of the design situation.

Output. The outcome of this phase is a critically reframed problem statement that serves as the foundation for subsequent futures-oriented and speculative activities.

Phase 2: Techno-Ethical Futures Framing

Purpose. This phase extends the design problem into future contexts and encourages students to consider its technological, social, and ethical implications. The emphasis shifts from understanding the current situation to exploring how emerging conditions may reshape the problem over time.

Activities. Students work with cards representing technological drivers, future conditions, stakeholder roles, and ethical conflict indicators. Using these prompts, they generate "What if…?" propositions and reformulate the design challenge as a futures-oriented and value-sensitive question. The activity encourages students to examine possible interactions among technology, society, and human values.

Output. The output is a scenario-oriented problem formulation that incorporates future conditions, ethical tensions, and alternative trajectories of change.

Phase 3: Scenario Worldbuilding

Purpose. In this phase, speculative ideas are developed into coherent socio-technical systems. Students move beyond isolated design concepts and begin constructing broader scenarios that integrate technological, social, cultural, and political dimensions.

Activities. Students define the context of the scenario in terms of time, place, and scale, and describe how technologies, social practices, and institutional structures interact within everyday life. They identify moments of tension through which ethical conflicts become visible and use impact-mapping exercises to examine consequences for different stakeholder groups across multiple time horizons.

Output. The result is a coherent socio-technical scenario that explicitly incorporates ethical tensions and their potential implications.

Phase 4: Speculative Design Intervention

Purpose. This phase introduces speculative interventions intended to reveal, intensify, or make visible the tensions embedded within the constructed scenario. Rather than seeking immediate solutions, students explore how design can function as a medium for inquiry, critique, and discussion.

Activities. Students select an intervention format, such as a product, service, product–service system, or regulation/protocol. They define how the intervention operates within the scenario and analyze its ethical, social, and systemic implications. Particular attention is given to what the intervention reveals, which groups may benefit or be disadvantaged, and which tensions it may reinforce.

Output. The output consists of a Speculative Intervention Sheet accompanied by a visual representation, such as a sketch, diagram, or conceptual artifact.

Phase 5: Reflection and Cognitive Reconfiguration

Purpose. The final phase emphasizes critical reflection and cognitive reconfiguration. At this stage, the focus shifts from generating design proposals to interpreting, evaluating, and reconsidering the learning experience as a whole.

Activities. Students participate in group presentations, structured discussions, and reflective exercises designed to encourage multiple perspectives on the developed scenarios and interventions. These activities support the examination of assumptions, ethical implications, and alternative viewpoints. Students then complete an individual Reflection Sheet documenting their learning process and critical insights.

Output. The outcome of this phase is not a design product but a form of cognitive reconfiguration, reflecting changes in students' understanding of design, the nature of the problem, and their professional responsibilities as designers.

6. Discussion and Conclusion

Bridging Critical Design Discourse and Design Education

The primary objective of this study was to develop a structured framework for integrating SCD into undergraduate industrial design education. While critical and speculative design have gained increasing theoretical attention, their educational application often remains fragmented and disconnected from studio-based learning activities. Existing approaches frequently introduce critical concepts through isolated exercises, theoretical discussions, or individual methods without providing a coherent pedagogical structure that links critical inquiry, futures thinking, and design practice. The proposed framework addresses this challenge by organizing these elements within a sequential yet flexible learning process (Tonkinwise, 2011; Bardzell & Bardzell, 2013; Bayne & Ross, 2024). The empirical evidence generated through curriculum analysis and the educational workshop was central to shaping the structure of the proposed framework. The curriculum analysis revealed that although critical, speculative, and futures-oriented themes are increasingly present in industrial design education, they are often introduced as separate topics rather than as an integrated learning progression. Similarly, the workshop findings indicated that different SCD tools supported distinct learning processes: some primarily encouraged imagination and futures exploration, while others supported ethical reasoning, critical reflection, and structured analysis. These findings informed the sequencing of the framework phases and supported the integration of complementary educational mechanisms rather than the adoption of a single design tool or method.

A key contribution of the framework lies in its proposed integration of complementary learning mechanisms. the evidence synthesized in this study suggests that futures-oriented and game-based activities can support imagination and alternative scenario generation, whereas analytical and reflective frameworks can contribute to critical reasoning and evaluation (Grace, 2014; Candy & Dunagan, 2017; Brookfield, 2017). By combining these approaches within a structured sequence, the framework provides a pedagogical pathway through which students can move from critical problem exploration toward speculative intervention and reflective learning.

Consequently, the framework may contribute to ongoing discussions regarding the role of critical and speculative design in design education by positioning these approaches not merely as design methods, but as components of a broader learning process capable of supporting engagement with complex socio-technical challenges (DiSalvo, 2012; Dunne & Raby, 2013; Malpass, 2017, p. 49; Mitrović et al., 2021).

Reframing the Role of the Designer in Speculative and Critical Design Education

One of the most significant theoretical implications of the proposed framework is its shift from solution-oriented design toward critical problem reframing. In conventional design education, design problems are often treated as predefined entities requiring efficient and functional solutions (Cross, 2006; Meyer & Norman, 2020). In contrast, the proposed framework encourages students to question assumptions, examine value structures, and explore the social and ethical dimensions embedded within design situations (Irwin, 2015; Escobar, 2018). This perspective is consistent with critical design theories that regard design not merely as a problem-solving activity, but as a means of inquiry, reflection, and social critique (DiSalvo, 2012; Dunne & Raby, 2013). Within this context, the framework encourages a reconsideration of the role of the designer. Rather than acting solely as a solver of predefined problems, the framework encourages students to consider the designer's role as a critical actor capable of revealing hidden assumptions, questioning dominant narratives, and examining the broader implications of technological and social change (DiSalvo, 2012; Malpass, 2017).

The speculative intervention phase of the framework is particularly important in enabling this type of learning process. Instead of encouraging students to optimize existing conditions, it invites them to create interventions that expose tensions, provoke discussion, and generate alternative perspectives. Such activities position design as a medium for critical engagement rather than solely as a vehicle for practical problem resolution. Furthermore, the framework promotes futures literacy and systems thinking by encouraging students to construct and evaluate socio-technical scenarios. Through the exploration of relationships among technology, society, ethics, and governance, students are encouraged to move beyond product-centered perspectives and develop a broader understanding of design as an intervention within complex systems (Auger, 2013; Escobar, 2018). In this sense, the framework may support the development of critical thinking as well as socially and ethically informed design practice.

Compared with existing approaches that often employ speculative and critical methods as individual classroom activities or workshop-based interventions, the proposed framework contributes a structured pedagogical sequence that connects problem reframing, futures exploration, speculative intervention, and reflection. Rather than replacing existing tools, the framework provides an educational structure for selecting and combining them according to specific learning objectives.

Pedagogical Implications

The proposed framework offers several implications for industrial design education. First, it provides educators with a structured model for integrating critical and speculative approaches into existing curricula without requiring a complete redesign of educational programs. The framework can be implemented as a standalone workshop, a short educational module, or as part of studio-based design courses.

Second, the framework demonstrates how different learning tools can be combined to support complementary educational outcomes. The integration of game-based, speculative, analytical, and reflective activities allows educators to address multiple dimensions of learning, including creativity, futures thinking, ethical reasoning, critical reflection, and systems awareness. Such

integration may contribute to more balanced and comprehensive learning experiences than approaches based on a single method or tool.

Finally, the framework's sequential but flexible structure allows adaptation to different educational contexts, themes, and levels of complexity. Although developed within undergraduate industrial design education, its underlying pedagogical principles may also be relevant to other design disciplines that seek to foster critical inquiry, futures-oriented thinking, and socially responsible design practice.

Conclusion

This study developed the Problem Reframing Framework for Speculative and Critical Design Education as a structured learning model for undergraduate industrial design education. Drawing on theoretical foundations, curriculum analysis, and empirical educational evidence, the framework was designed to organize critical inquiry, futures thinking, systems awareness, ethical reasoning, and reflection within a coherent learning sequence. The framework is designed to encourage students to examine assumptions, explore alternative futures, construct socio-technical scenarios, and reflect on the implications of design decisions. In this way, the framework positions design as a medium for inquiry, reflection, and critical engagement with complex socio-technical challenges. The framework therefore offers a pedagogical approach that may support the integration of Speculative and Critical Design within undergraduate industrial design education and provides a foundation for further educational experimentation and research.

Limitations and Future Research

Several limitations should be acknowledged. The framework was developed through the synthesis of theoretical and empirical evidence and has not yet been implemented and evaluated as a complete educational intervention over an extended period. Future research should therefore examine its application in different educational settings, investigate its potential contribution to students' critical and futures-oriented competencies, and explore how the framework may be adapted for other design disciplines and interdisciplinary learning contexts. Proposed future evaluation of the framework should include clearly defined learning outcomes and assessment criteria aligned with its intended educational objectives. For example, critical thinking may be evaluated through students' ability to identify assumptions and justify design decisions; problem reframing through the quality of alternative problem formulations; futures literacy through scenario construction and evaluation; ethical reasoning through analysis of value conflicts and stakeholder perspectives; systems thinking through examination of socio-technical relationships; and reflective practice through structured reflection activities. Future studies may employ expert validation, pilot implementation, pre- and post-assessment, comparative educational groups, rubric-based evaluation of student outputs, and longitudinal studies to examine the educational value and applicability of the framework. The present article represents the framework development stage of a larger DBR trajectory; therefore, full implementation and longitudinal evaluation are beyond the scope of this manuscript.

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