Article

How HCI Integrates Speculative Thinking to Envision Futures

Lin Zhu[1], Chiyu Chao[1], Zhiyong Fu[1*]

[1]*Departments of Academy of Arts & Design, Tsinghua University, Beijing, China*

Abstract

This scoping review explores how speculative thinking approaches have been leveraged within the field of Human-Computer Interaction (HCI) to envision and shape potential futures. Speculative thinking methods such as speculative design, critical design, design fiction, and design futures incorporate imagination, extrapolation, and fictional elements to expand the range of conceivable future scenarios. Despite their growing significance within HCI research, their implementation and application have yet to be clearly defined. It becomes evident through this review that there are three ways in which HCI constructs futures in conjunction with speculative thinking. There is an underscored need for more systematic and rigorous approaches to the deployment and evaluation of multiple futures within HCI research. The importance of methods and tools within HCI education to cultivate speculative thinking skills among students and practitioners is also stressed. The Design Futures research process is proposed to provide a structured approach to exploring and shaping possible futures, benefiting the HCI field. This work aims to serve as an intermediary between the Design Futures community and HCI, thereby facilitating cross-disciplinary collaboration and advancing speculative thinking within HCI.

Keywords

Introduction

In the realm of Human-Computer Interaction (HCI), three evolutionary stages have been identified, with the current Third Wave emphasizing the exploration of relationships among humans, institutions, and technology. The utilization of speculative thinking in HCI research boasts a rich history, as it is a cognitive process that delves into the imaginative examination of possibilities, potentialities, and alternative futures (Bardzell & Bardzell, 2014). This method has been employed to assess the impact of emerging technologies, stimulate discussions and debates about the future, and generate novel concepts and innovations. This paper elucidates speculative thinking as a mode of thought that bridges and connects design and HCI disciplines and knowledge domains. It encompasses a range of approaches, such as critical design (Dunne & Raby, 1997), Design Fiction (Bruce, 2005), speculative design (Dunne & Raby, 2013), Speculative Enactments (Elsden, 2017), and others, which collectively examine the potential influence of technology on society and human experiences. Despite the diversity and evolution of these approaches, they have garnered recognition as Third Wave HCI research integrates broader societal considerations (Feltwell et al., 2018; Keyes et al., 2019; Os Hoy & Drouhard, 2019). Although no explicit evidence connects speculative thinking to the Third Wave, the temporal correlation underscores the convergence of speculative thinking between Design and HCI.

Futures studies aim to predict various potential futures and continuously evaluate them in a cyclical manner to achieve a preferable outcome (Dator, 2011). As a multidisciplinary field, it has been applied to corporate strategy, public policy, design, and HCI (Kozubaev, 2016). The primary motivation for HCI's interest in speculative thinking is to envision and discuss future possibilities. As speculative thinking is one of the essential dimensions of Futur

* Corresponding author.

E-mail addresses: zhu-l20@mails.tsinghua.edu.cn(L. Zhu), zjr21@mails.tsinghua.edu.cn (C. Chao), fuzhiyong@tsinghua.edu.cn (Z. Fu),

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es Studies, we investigate the diverse contexts and scopes of employing speculative thinking in HCI, the varying interpretations of futures, as well as the current limitations and future directions for envisioning futures. Despite the coexistence of interests and confusions, limited research has been conducted to provide an overview of how HCI has adopted speculative thinking to envision futures. Addressing this gap, our study conducted a scoping review of existing HCI publications that claim to utilize speculative thinking. The objective was to present a comprehensive analysis of how HCI envisions futures, the dimensions of futures deemed relevant to HCI, and the unexplored or underexplored design and research areas. To identify future envisioning in the application of speculative thinking in HCI, we performed a trend analysis of HCI literature on speculative thinking by adopting a twostep groundedtheory approach involving Open Coding and Axial coding (Strauss & Corbin, 1990). Our multilevel analysis consisted of two primary objectives. First, we aimed to identify trends in the research field and the crosslinkages between speculative thinking design and HCI. To achieve this, we conducted a quantitative analysis of the technology enablers used in the papers and the emerging research areas and methods. Second, our objective was to comprehend how HCI defines and integrates speculative thinking, including its logic, scope, and potential. For this purpose, we carried out an inductive content analysis to examine the presence and impact of speculative thinking in HCI for generating future artifacts and scenarios, exploring its form and perception from multiple perspectives. Before presenting our findings, we will first review the speculative thinking content and the related work on clarifying the intersections between HCI and futures studies.

Related Work

Explorations of futures in HCI

Human-Computer Interaction (HCI) research has identified several aspects related to "the future" as a framework for design thinking, with the concept of technological imaginaries being fundamental (Bardzell & Bardzell, 2015). Futurists and AI researchers are thus very likely to face substantial issues that need to be resolved in the future together while mitigating ethical concerns (Diaz-Dominguez 2020). While HCI predominantly emphasizes short-term outcomes (Amara, 1974), it also maintains a generative fringe that fosters transformative work at the periphery, introducing innovative concepts into the normative domain, which is essential for establishing disciplinary rigor and commonality. Mankoff et al. (2013) champion the application of Futures Studies methods to expand HCI research horizons, providing a thorough classification and adaptation of these methods within the HCI domain. By employing the Delphi Method, they showcase the seamless integration of Futures Studies into HCI, underscoring the importance of future work, such as reevaluating the role of externalities in the validation process. Leading HCI publication venues, such as CHI (Computer Human Interaction Conference), have emphasized speculative thinking since the early 21st century (Source: Google Scholar metrics). For example, a CHI2014 report presents an intriguing collection of fictional abstracts that could appear in the CHI 2039 conference proceedings, prompting contemplation on the diverse visions shaping HCI's trajectory (Baumer et al., 2014). The Conference on Designing Interactive Systems (DIS) has also concentrated on the intersection of speculative thinking and HCI since 2020, featuring dedicated tracks on future scenarios (Kozubaev, 2016; Pandey & Culén, 2018). NordiCHI follows suit with tracks on Future Scenarios. Futures studies offer valuable methods for supporting long-term trend analysis, pinpointing innovative research areas, and guiding design and evaluation. In recent years, there have also been several papers on journal Futures discussing the futures within HCI. Gandy et al. (2017) put forth a futures-based, iterative policy-informed design framework for wearable devices development, directing interdisciplinary collaborators early in the research and development planning process. Pargman et al. (2019) employ "fictional abstracts" to stimulate ideas and facilitate discussions on contemporary researchers' aspirations and apprehensions about future computing. A literature analysis reveals that HCI lacks a lucid definition of generating futures, and its applications are multifaceted and interwoven.

The essence of speculative thinking

As a pragmatic, user-experience-centric discipline, HCI holds the potential to devise groundbreaking methods for direct interaction and immersive engagement with speculative design projects (Elsden et al., 2017). Richmond et al.

conduct a systematic examination of speculative design within HCI, positing that design artifacts should be harnessed to communicate future scenarios or introduce novel design possibilities, a prevalent aspect in critically-oriented Third Wave HCI. The definition of speculative thinking in this paper bears similarities to Discursive Design, which encapsulates or deliberately generates ideas of psychological, sociological, and ideological importance through artifacts (Tharp & Tharp, 2019). Both terms encompass existing and future designs that express ideas through specific design outputs, covering similar designs in terms of form, content, and objectives.

This paper's speculative thinking integrates tools and methods organically proposed by the HCI field, aiming to distill its characteristics from a collection standpoint and concentrate on the forthcoming development trend. Figure 1 enumerates some of the most widely cited theories or claims with speculative properties in HCI and Design since the inception of the Third Wave.
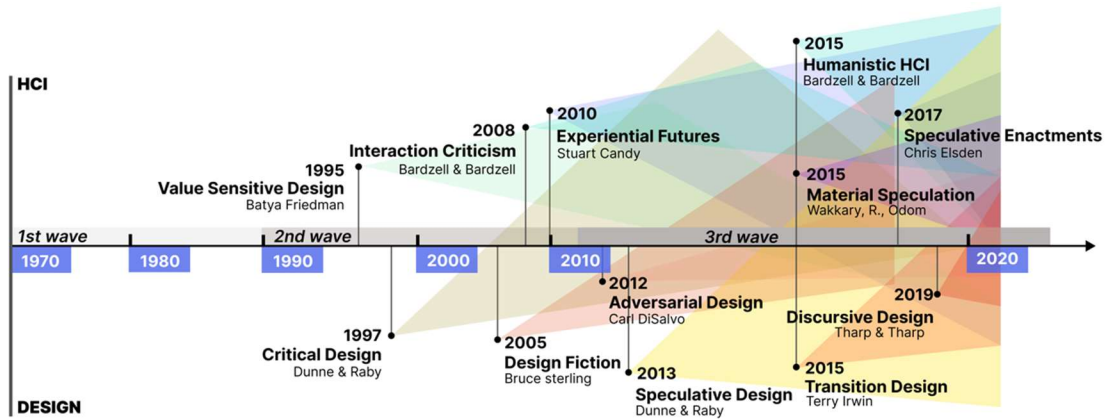

Fig 1: Some speculative theories and propositions from 1995 to 2022

Previous research (e.g., Kelley, 1983; Dahlbäck et al., 1993) demonstrates that computer science scholars and HCI practitioners have effectively devised, implemented, and constructed speculative design research. Dunne and Raby introduced "critical design" in the mid-90s and popularized "speculative design" in their book "Speculative Everything," defining it as design that interrogates potential technological futures (Dunne & Raby, 2013). Design fiction, first coined in 2005, describes an innovative approach to crafting thought-provoking scenarios that enhance understanding of emerging technologies and social trends' implications (Bruce, 2005). Bleeker (2009) has extensively written on design fiction and advocated for its use as a tool to explore the social and cultural implications of emerging technologies. Numerous theories with speculative properties have emerged or been produced in parallel within the HCI field. Despite its reputation as a cutting-edge approach in HCI and design research, design fiction has been a vital component of speculative design research for the past three decades (Jordan & Silva, 2021). "Material Speculation" distinguishes itself from Design Fiction by proposing a "preconceptual bridge" between the audience and fiction through tangible, functional artifacts in the real world (Wakkarym et al., 2015). "Experiential Futures" offers a path for participants to engage in speculation beyond generating critical discourse with the audience (Candy, 2010). The term "humanistic HCI" was not formally or consistently used within the field before its publication (Bardzell & Bardzell, 2015). Discursive design, according to Tharp & Tharp (2019), transcends conventional utility to stimulate self-reflection, ignite imagination, and inspire societal change by utilizing objects as catalysts for new thinking.

Elsden (2017) introduced speculative enactments as a novel way to involve participants in research, inviting them to conduct empirical analysis within a provided scenario using speculative artifacts.

While the aforementioned studies reveal intersection between the two fields and offer implications for future research agendas, they do not provide a comprehensive overview of speculative thinking's current positions in HCI, and their empirical findings are rarely synthesized. Addressing these limitations, this study aims to synthesize existing research through a scoping literature review of HCI publications utilizing speculative thinking. Our primary

research question is how HCI adopts speculative design to envision futures. Informed by the related works above, our analysis specifically aims to explore the following questions:

- What approaches of speculative thinking have been adopted in HCI to envision futures?
- What are the impacts of Futures studies intervention on HCI research?

Method

Search strategy

The scoping review was carried out according to the guidelines set forth in the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) statement (Moher et al., 2009). The main objective of the review was to identify literature within the field of HCI that utilizes speculative thinking in some form, whether as a process, method, logic, or practice. The main data sources used for the review were the Web of Science and SCOPUS databases. The search was restricted to papers with the term "Speculative HCI" in the title, abstract, or keywords, as the goal was to analyze papers in which speculative thinking and its associated theories played a prominent role. The term "Speculative HCI" was chosen over "Speculative Design and HCI" to ensure that relevant research was not missed due to differences in terminology. The time frame for the search was from the first appearance of speculative design in HCI up until the year 2022. The results of the search are detailed in the appendix.

Article screening

The screening procedure, illustrated in Figure 2, was carried out on all 97 English language papers that were found in the database, to identify those that were from the field of HCI and clearly demonstrated how speculative design has influenced or been integrated into the study.
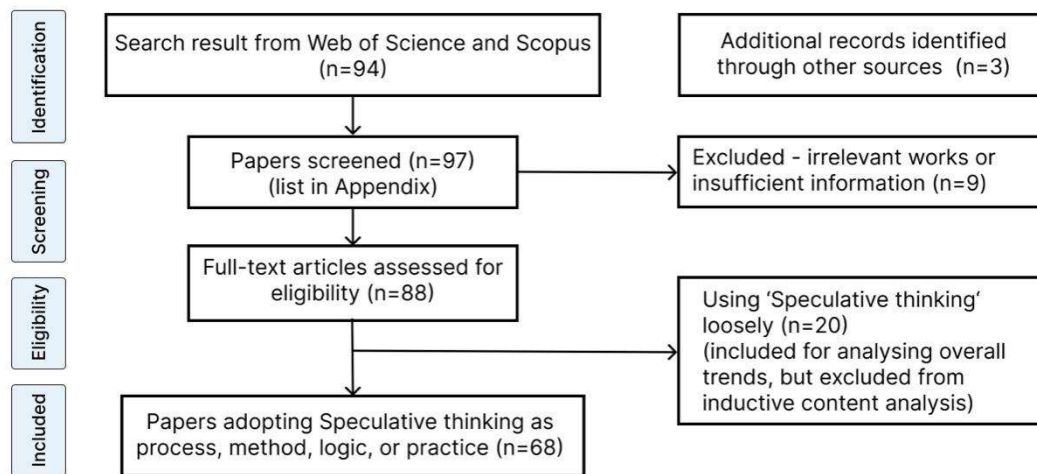

Fig 2: The article screening procedure in this study.

After screening, 88 papers were shortlisted for analysis. Of these, 20 were classified as "Using Speculative Thinking Loosely," as they only briefly mentioned speculative design without discussing it extensively. The remaining 68 papers were categorized as "Adopting Speculative Thinking as a Process, Method, Logic, or Practice," as they demonstrated the use of speculative design theories. Although workshop proposals may lack detail, the majority were held at CHI, indicating the increasing specificity of the HCI field regarding speculative design. The final analysis included all 68 papers in this category. The full list is in the appendix. The 20 papers in the "Using

Speculative Design Theories Loosely" category were included in the quantitative analysis but excluded from the inductive content analysis as they did not provide relevant insights.

Overview of speculative thinking adoptions in HCI

To understand the temporal distribution of HCI research focused on speculative design theories, we initially mapped all 97 papers collected from the Web of Science and SCOPUS databases on a timeline. As depicted in Figure 3, the earliest introduction of the keyword "speculative design" in the HCI research field was in an ACM conference paper by the Experimental Documentation Research (RED) Group, which was published at CHI (Computer Human Interaction) in 2000 (Balsamo et al., 2000).
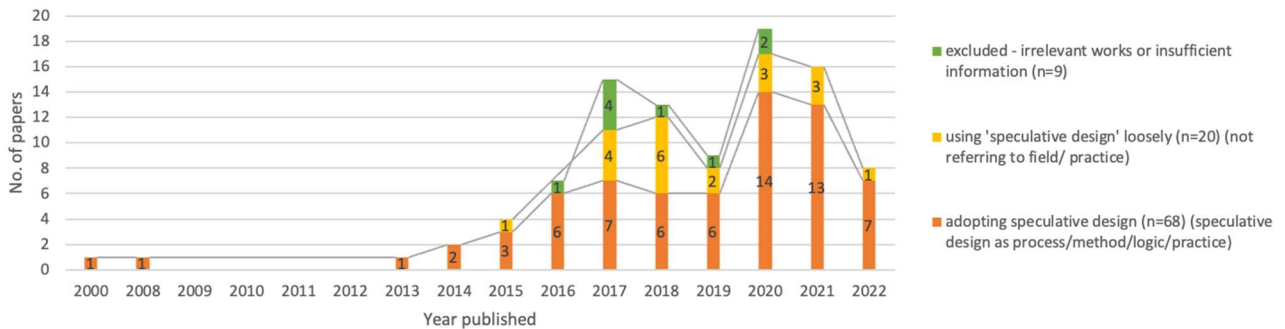

Fig 3: Search result from the data source over the years (2000-2022)

Domains. The various domains where speculative thinking was applied were analyzed for the 88 papers, 68 of which were categorized as adopting speculative design theory and 20 as using speculative design theories loosely, to examine the application domains within the field of HCI. The broad categories can be divided into two: (1) Application, meaning design experiments or implementation through speculative thinking, with notable emerging sub-themes such as sexual HCI (e.g., Troiano et al., 2020), feminist HCI (e.g., Croon, 2022), indigenous nations (e.g., Akama et al., 2016), online behavior (e.g., Kiskola et al., 2022), climate change (Beach & Fox, 2021), and game design (e.g., Spiel & Nacke, 2020). (2) Design method discussion, mainly on case studies (e.g., Pierce et al., 2015), discussions on the application of speculative thinking in HCI (e.g., Rogers et al., 2019), and reflections on HCI education (e.g., Jordan & Silva, 2021). According to Rogers et al., speculative design necessitates students to apply their design skills (visual artifacts, storytelling, creative problem solving, etc.) in novel and complex ways, which contributes to their growth in voice and perspective (Rogers et al., 2019). Workshops are frequently organized to foster discussions within the HCI community

Application of the theory. Given that the applications of Speculative thinking that we focus on in this paper include speculative design, critical design, design fiction, design futuring, and criticism, we first sort out the applications mentioned and used in each paper (n=68) in Table1.

Table 1: Design theories application

Design theories mentioned in paper	2000	2008	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	Total (%)
Design futures/ design futuring			1			1			3	1	1	1	8 (12%)
Critical design, speculative design, and design fiction			1	1	1	5	3	2	6	6	2		27 (40%)
Speculative design & design fiction						2	2		1	3	3		11 (16%)
Speculative design & critical design				1		1	1		1		3	3	10 (15%)
Speculative design	1					2		2	2	3	3	2	15 (22%)
Design fiction			1			1		1					3 (5%)
Criticism			1										1 (2%)

Technology Enablers. We mapped the technology enablers over the years to identify possible trends in Table 2. The recent use of speculative thinking has brought attention to the potential effects of advancements in technologies such as virtual reality, artificial intelligence, and the Internet of Things. Additionally, it has been employed to evaluate the societal and cultural implications of these technologies and foster discussions on the ethical and policy concerns they pose. This shift in computing, which has brought it from the workplace to daily life and from desktop to mobile and physical devices, highlights the importance of contextual understanding (Dourish, 2004; Harrison et al., 2007). Speculative Enactments offer the opportunity for empirical analysis by allowing participants to engage in speculative but significant circumstances (Eldsen, 2017). The incorporation of augmented and virtual reality technologies has added to the experiential aspect of future projections and more HCI researchers are utilizing this method to perform empirical studies on technological visions.

Table 2: Technology enablers over the years

Technology Enablers	2015	2016	2017	2018	2019	2020	2021	2022	Total
Interactive urban intervention						2	2		4
Renewable energy						1			1
Internet of bodies (IoB)			1	1		2	1	1	6
AR/VR/MR/XR			1				2	1	4
Synthetic biology							1		2
Digital gift							1		1
Civic tech		1				1	1		3
Autonomous driving							2		2
IoT	1		1	1	1	1	1		6
Self-tracking			1		1	1			3
Counterfactual sound space	1	1				1			5
Wearable, Embodied speculation			1			1			2
Emotion visualization			1				2		3

Methods Used to Envision Futures. As adoption of methods indicates the adoption of practices, we also looked at what kinds of methods that are known as ideal methods have been used in the 68 papers categorized as "adopting speculative thinking as a process, method, logic, or practice" to envision futures. We found a number of papers in the collection that focus on futurological tools and use them for analysis. We first refer to Mankoff's classification of Synergies with HCI by listing the common methods used to conduct experiments and studies mentioned in each of the papers as coding, as detailed in Table 3.

Table 3: Methods used over the years

Futures Studies methods		Synergies with HCI	2013	2015	2016	2017	2018	2019	2020	2021	2022	T
1.Behavioral techniques (intuitive)	Delphi method	Interview			1	2	1		1	1		6
		Fictional reviews				1			1			2
	Workshop	Futures workshop				1		1	1	1	1	5
	Scenario-based method	Story Complete method				**1**		**1**	**2**	**1**		5
		Speculative video							**1**	**1**		2
2.Monitoring (interpretive)	Environmental scanning	Fieldwork	1		2			1	1		3	9
3. Simulation and Modeling (Computational)	Human computation	Rapid prototyping				1	2		2	1	2	8
		Probes		2		2	1		2	2		9
4.Reflection (Critical)	Action learning	Observation							1	1		2

Story Complete Method (SCM) like the use of personas and scenarios in HCI, SCTs ask participants to write in the third person, rather than providing personal responses, thus decreasing concerns around social 'desirability'. Wood et al. see SCTs as a promising research tool for HCI, particularly for speculative enquiry, suggests that this was a useful tool in doing exploratory work, and an effective way of investigating an area which would be difficult, or ethically challenging, to explore using face-to-face data collection. Synergy with HCI Delphi methods has been used for HCI prediction (e.g., Ashford, 2021), usually at the larger project level, and is not widely accepted as a normal part of the design process. Workshops (originally derived from the Futures Workshops used in participatory design) may be used to help small groups envision alternative futures and guide decision-making (Dator, 1993). Scenario-based techniques have been used in HCI to explore how users will react to future technologies or to explore future needs (Wood et al., 2020). Scenario-based methods can be improved by using structured methods from futures research to reduce bias and increase the range of futures under consideration. These instrumental methods help HCI researchers to use futures research techniques more extensively as part of the study planning process to enhance the salience of potential design results.

Dimension (D)	Code (C)	2008	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	T(%)
D1: Authors' Department	C1-1: Computing and Science		1					1	3	1	4	3	13 (19%)
	C1-2: All from design					3	3	2			5	6	19 (28%)
	C1-3: HCI domain with design						3	2	2	5	3	2	17 (26%)
	C1-4: Design domain with HCI				2	1	1	1	1	1	2		9 (13%)
	C1-5: Informatics, communication	1		1		2	1					2	7 (11%)
D2: Scope of HCI	C2-1 Interface design							1		1	2	1	5 (7%)
	C2-2 Interaction Criticism	1	1		2	3	3	2	1	4	2	3	22 (33%)
	C2-3 intelligence, agency, digital platform					1		2	3	1	1		8 (12%)
	C2-4 Emerging tech					1	2		2		1		6 (9%)
	C2-5 User Experience design					1	3	1	1	5	7	3	21 (31%)
D3: Research contribution	C3-1: Internal reflection / arise awareness & discussion					1	2	5	2	2	5	2	19 (28%)
	C3-2: output-website, corpus, tool			1					1		1	2	5 (7%)
	C3-3: Design objects							2	2	1	2	3	10 (15%)
	C3-4: New concept	1	1		1	2	1	1	1	4	8	6	26 (39%)
D4: The usage of Speculative thinking	C4-1 test or get the user feedback						1	1	1	2	3	4	13 (20%)
	C4-2 Envision future scenario			1				1		1	3	3	9 (13%)
	C4-3 Generate/reflect new theories or methods			1		2	3	2	5	2	4	3	24 (36%)
	C4-4 Expend the boundary						1	3		1	1	1	7 (11%)
D5: Evaluation method used in the research	C5-1: Self-set or propose a new way					1	1		3	5	4	5	22 (33%)
	C5-2: Follow others							2		4	4	2	12 (18%)
	C5-3: Do it later								1				1 (1%)
	C5-4: Not mention					1	1	5	3	2	4	2	18 (26%)
D6: Facing problem	C6-1: Engaging with the theory		1			1	2	3	2	1	5	3	19 (28%)
	C6-2: Lack of example / tools / theory			1				1	3	1	5	4	17 (26%)
	C6-3: Fuzzy definition/understanding					1		2		2	5		10 (15%)

Fig 4: The number of papers coded under the six dimensions

Qualitative Analysis

Our analysis first focused on uncovering overall patterns and then conducted a thorough analysis to identify the dimensions of the adoption of speculative design theory in HCI. To begin, the 88 papers (68 categorized as adopting speculative design theory and 20 categorized as using speculative design theories loosely) were mapped based on the year of publication, HCI domain, technology enablers, and research methods used. The first author initiated the analysis by performing open coding on the papers, resulting in 50 codes. The first and second authors then collaboratively discussed the dimensions (6) and codes (24) and used these codes to independently code all 68 papers. The first and second authors held three meetings to discuss and resolve any discrepancies in their coding.

The inductive content analysis produced 24 codes organized under six dimensions: D1-Authors' Department, D2-Scope of HCI, D3- Research Contribution, D4- Usage of Speculative Design Theory, D5-Evaluation Method used in Research, and D6-Facing Problem. D1 tells us departments of the authors of the paper; D2 indicates the research focus segments; The rest focus on the specifics of the research in progress. Each paper was coded multiple codes (e.g., Troiano et al., 2020) was coded (C1-3, C2-2, C3-4, C4-2, C5-2, C6-2). Figure 4 shows the distribution of papers, but the percentages do not add up to 100% because not all papers belong to a dimension. In the following sections, we will explore the dimensions to understand the current integration of speculative thinking and human-computer interaction.
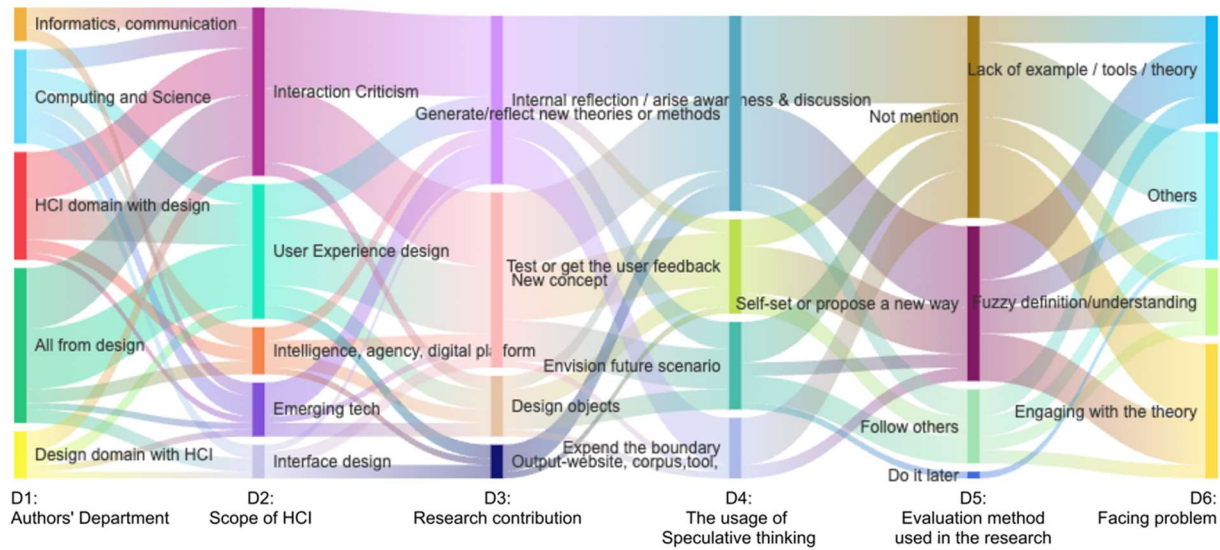
Results

Fig 5: Dynamic Sankey diagram of coding

Overview of the integration

Our scoping review of Human-Computer Interaction (HCI) literature reveals an increasing interest in employing speculative practices to stimulate discourse on the future of technology and its societal implications. Through the above coding analysis, we arranged the dimensions listed in Figure 4 horizontally and the corresponding codes vertically, and generated a dynamic Sankey diagram to discuss the co-occurrence relationship between codes. Further try to summarize several kinds of approaches to envision the future, see figure 5. In terms of author background composition, the majority of authors come from a background that combines HCI and design in a collaborative manner. Speculative thinking has bridged the gap between these interdisciplinary teams, allowing them to collectively address complex issues. This has led to a shift from mutual learning between disciplines to frequent exchanges and eventually, the of disciplines to address specific problems. Various paths to envisioning the future have been identified. For instance, design methods have been applied to the field of computing to solve HCI problems. Designers play a crucial role in that offer more immersive experiences (Candy, 2010). HCI's empirical research methods have also been used to and optimize the design of future application scenarios. Designers are often the primary authors in projects, creating future visions for topics that are then tested by users (Culen & Stevens, 2021). They may also participate in experiments or workshops as subjects themselves (Boehner & DiSalvo, 2016). Furthermore, the methods of futures studies have been employed in design and computing to address broader social issues that affect a wider audience. However, as interdisciplinary exchanges become more frequent and close-knit, several challenges have emerged. These include the lack of theories and tools suitable for multiple disciplines, unclear processes and guiding frameworks, and the absence of platforms for information exchange. These issues need to be addressed to further enhance the transdisciplinary collaboration.

Three approaches to envision futures

In the realm of Human-Computer Interaction (HCI), speculative thinking consistently intertwines with future-oriented contemplation, fostering opportunities for interdisciplinary approaches and theories from Computer Science, Design, and Futures Studies to converge. To better comprehend the origins, dissemination, and application mechanisms of these theories, we first examined 68 papers, identifying the most frequently cited and utilized speculative thinking theories. Based on the authors' disciplinary backgrounds, these papers can be broadly classified into three approaches: Multidisciplinary, Interdisciplinary, and Transdisciplinary. To further investigate HCI's envisioning of the future through Speculative Thinking, we have organized related dimensions, intentions, form,

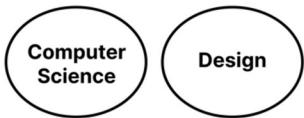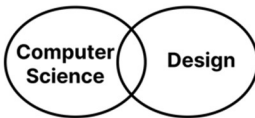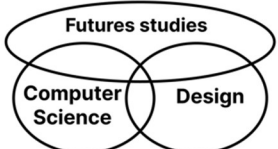and envision, as illustrated in Figure 6.

Approach	Multidisciplinary	Interdisciplinary	Transdisciplinary
Dimension	Project exploration	User research	Social groups
Intention	Expend boundary	Build scenario	Generate methodology
Form	Self Speculation	Quantitive analyse	Speculation guidance
Envision	Possible futures	Probable futures	Preferable futures

Fig 6: Three approaches of the Integration

Multidisciplinary. Occurs when the solution to a problem makes it necessary to obtain information from two or more sciences or sectors of knowledge without the disciplines drawn on thereby being changed or enriched (Piaget, 1972). This approach draws from methods and tools extensively discussed and employed in the design field. By repurposing these methods and tools for HCI research, scholars aim to stimulate reflection and liberate themselves from existing cognitive constraints. Notably, 22 papers in this study classify speculative design, critical design, and design fiction as subcategories within a broader category, partially grouped as Design Futuring. The amalgamation of speculative design and design fiction is prevalent, with some researchers considering this combination complementary. However, Rogers et al. (2019) argue that design fiction often lacks criticality and tends to glorify technology, rendering it more appropriate as a figurative representation following the application of speculative design (Tsai et al., 2020). Some researchers concentrate on bridging the theoretical gap by involving the public through websites, corpora, or tools. Certain works have emerged from the aspiration to integrate cultural criticism into design, acknowledging the necessity for supplementary methodological and conceptual frameworks to support HCI researcher

Interdisciplinary. Is where cooperation among various disciplines or heterogeneous sectors in the same science led to actual interactions, to a certain reciprocity of exchanges resulting in mutual enrichment (Piaget, 1972). This approach proposes additional or more suitable speculative theoretical methods for HCI. These methods emphasize a pragmatic, experience-centered, and participant-focused approach, facilitating empirical analysis of participants engaging in speculative yet consequential contexts. Although Dunne & Raby introduced the characteristics of speculative design, its definition and examples remain abstract, causing confusion in the qualitative and quantitative analysis and evaluation of speculative design. In conventional speculative design, enactments have been critically oriented to generate discourse and promote agendas that challenge prevailing practices in technology design (Wong and Khovanskaya, 2018). Wood et al. (2017) conducted a speculative inquiry into the emerging technology of virtual reality (VR) pornography, examining the perpetuation of conventional assumptions about pornography and the negotiation of VR's reality in a sexual context. Elsden et al. (2017) contend that a more practical perspective to learn from people's interactions with and experiences of speculation, citing the need to engage people more viscerally in future conversations. Material Speculation suggests the necessity of establishing a perceptual bridge between the audience and fiction through tangible, functional artifacts that inhabit the actual everyday world（Wakkary et al.,2015).

Transdisciplinary. Takes this integration of disciplines a step further. It is a holistic approach. It is not just about

interactions between specialized fields, but about placing these interactions in a total system with a social purpose. This approach endeavors to construct a speculative dialogue bridge. Speculative thinking challenges HCI's human-centered design proposition by promoting a forward-looking, scalable approach that surpasses the examination of cognitive behavior and interaction between individual users and interfaces. By considering people as citizens, the focus shifts from individual users to social groups. HCI has recently experienced a "civic turn" (Johnson et al., 2016), resulting in technology being utilized for more explicit political purposes, such as adversary design (DiSalvo, 2012), which addresses political issues and embraces conflict (Rogers et al., 2019). Employing creative approaches can encourage innovative thinking through their openness and ambiguity, but may also provoke discomfort, unease, or unintended consequences, particularly in group settings or when technology is involved. The potential for future risks prompted participants to reflect on current design trends, integrating broader ecological and political concerns into the conversation (Jewitt, Barke & Gol Mohammadi, 2022).

Discussion

In the field of Human-Computer Interaction (HCI) research, there is a significant focus on future-oriented projects. However, the exploration of methods used in academic HCI research has been somewhat limited. Speculative design goes beyond creating only positive future scenarios, encouraging a more detailed understanding of the implications of specific technological objects. It also promotes critical awareness of the inherent capabilities and problem formulation in new technologies. The futures of various groups have shifted the previously uniformly positive perspective on technology's future. The range of these groups and their interconnected relationships have significantly expanded the scope of considerations. As a result, some researchers have voiced concerns that current speculation could lead to unintended outcomes and uncertain futures.

This scoping review includes papers that directly use futurological methods, such as the Future Cone (Kozubaev et al., 2020) and forecasting (Lindgren et al., 2021). An approach based solely on feasibility falls short in addressing multiple futures, limiting the scope of its results to the near future. Many researchers have pointed out the frequent lack of clarity about how Design Futures will generate new knowledge and contribute to HCI. This includes the presentation and experience of speculative work for participants and how user engagement will be understood. The lack of explicit guidance in HCI for anticipating multiple futures and assessing the long-term effects of technologies highlights the importance of interdisciplinary collaboration and the use of futurological methods.

This paper calls for a deeper involvement of Futures Studies in the conceptualization of the future in the field of HCI. This can benefit from the integration of design and Design Futures research processes, jointly providing a structured method to explore and shape possible futures. Design researchers actively explore approaches to future-oriented design projects, often using a process framework to guide a set of interrelated activities. For example, the Extrapolation Factory, located at the intersection of Speculative Design and Design Futures, uses the Future Scope a four-part thought tool designed to facilitate the development of imagined future scenarios. The Future Scope includes several precedent thought tools and strategies, such as horizon scanning, Voros' Futures Cone, and STEEP analysis. Evans (2012) presents a design-led futures framework to support designers in developing next-generation products and services, providing a mechanism to underpin future-oriented design projects. Additionally, Lin and Kim (2022) introduce a design approach that combines speculative design, value-sensitive design, and emotion-based ethnographic methods to identify value-experiences for the creation of value-driven speculative futures

Conclusion

This article reviews widely cited theories in human-computer interaction (HCI) and design since the third wave, providing a comprehensive overview of speculative thinking's application in HCI. From 97 collected publications, 68 were analyzed to reveal speculative thinking methods used in HCI, focusing on aspects like publication date, domain, theory application, technology enablers, and methods to envision futures. The authors independently coded the 68 publications, proposing three approaches to envision futures, indicate the transdisciplinary approach emerging as a promising long-term development model. The review highlights the potential of speculative thinking in shaping diverse HCI futures, identifies gaps in current literature. Future research should address these gaps by

developing more explicit guidance for anticipating multiple futures and assessing the long-term effects of technologies within HCI. Additionally, further exploration of interdisciplinary collaboration and the incorporation of futurological methods is warranted to advance the field and enhance the impact of speculative thinking on HCI education and practice.

Appendix

The full list of all 94 papers and how they are categorized in this study can be found at https://rich-seeder-dae.notion.site/List-of-papers-used-in-scoping-review-c93bd417bae44f5dabd90826416adf18

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