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Collaborating across Domains and Roles: An Interview Study of Visualization Design Practices

Yiwen Xing, Maria Teresa Ortoleva, Rita Borgo, and Alfie Abdul-Rahman

Abstract—Visualization design study is a widely adopted approach for developing tailored visual solutions to domain-specific problems through close interdisciplinary collaboration. While the visualization community has proposed generalizable frameworks, there is a growing need for domain-aware methodologies that address discipline-specific challenges and refine design study practices. To investigate how domain characteristics and collaborator roles influence the design study process, we conducted interviews with 15 experts, including domain specialists from the humanities, arts, applied sciences, and artificial intelligence, as well as visualization researchers and developers, with direct experience in design studies. Our findings reveal tensions and opportunities that arise from differing expectations, communication styles, and levels of engagement among collaborators at various stages of the design process, including problem formulation, co-design, and evaluation. We highlight how domain-specific norms and role dynamics shape collaboration and influence the trajectory of visualization projects. Based on these insights, we offer practical considerations to help visualization researchers anticipate domain-specific challenges, foster mutual understanding, and adapt their methods accordingly. Our study contributes to ongoing efforts to support more context-sensitive, sustainable, and inclusive design study practices across diverse application domains.

Index Terms—Design study, collaboration, interview study

1 Introduction

Domain-problem-driven visualization research – often conducted as a visualization design study, where visualization researchers collaborate closely with domain experts – has become a well-established approach for developing tools that address real-world challenges across disciplines [31]. Design study is now a standard mode of inquiry in this context, characterized by deep engagement with domain problems, iterative tool development, and critical reflection on both process and outcome [30, 31]. While the visualization community has proposed many guidelines and frameworks for conducting design studies, most remain domain-agnostic. In practice, however, visualization researchers often find themselves working in dramatically different disciplinary settings – ranging from history and digital arts to biology and artificial intelligence. This raises important questions: Are general-purpose frameworks and norms equally effective across such diverse domains? How do variations in domain expertise, research culture, and collaborator roles affect the way design studies are scoped, conducted, and experienced? Although visualization researchers frequently shift between domains, there are few resources available to help anticipate how domain-specific factors may shape collaborative dynamics, design expectations, or evaluation strategies. How can we better prepare for these domain differences and evolving team structures? And how might existing methodologies be adapted to support more context-sensitive, inclusive, and sustainable cross-domain collaborations?

This paper investigates how collaborative visualization design unfolds in practice across different application domains and collaborator groups. We report on a qualitative interview study involving 15 participants, including visualization researchers, software engineers, and experts from the humanities, arts, applied sciences, and artificial intelligence domains. This study examines how domain characteristics and collaborator roles influence the design study process, spanning from initial problem scoping to iterative development and evaluation.

Our contributions are threefold: 1) We explore how domain-specific cultures, working styles, and ways of thinking affect readiness for visualization, from both internal (self-reflective) and external (cross-role) perspectives. We identify recurring differences between the humanities, arts, and sciences that shape how collaborators perceive and approach visualization. 2) We characterize the influence of domain and collaborator roles on visualization design practices, highlighting common expectations and variations across different stages of the design study process. 3) We surface common tensions in cross-domain collaborations, including mismatched motivations and concerns about sustainability, and outline strategies for building mutual understanding. We reflect on domain proximity and individual visualization familiarity as two useful indicators for assessing readiness and guiding methodological adaptations before entering new collaborative contexts.

- *Yiwen Xing, Maria Teresa Ortoleva, Rita Borgo, and Alfie Abdul-Rahman are with King's College London, UK. E-mail: {yiwen.xing | maria-teresa.ortoleva | rita.borgo | alfie.abdulrahman}@kcl.ac.uk.*

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2 Background and Related Work

2.1 Who Are the Collaborators?

Collaborative visualization design projects typically involve contributors from diverse disciplinary backgrounds [9]. A well-established body of literature, including the ViSC report [22] and the role typologies synthesized by Kirby and Meyer [17], emphasizes that the success of such projects relies on assembling interdisciplinary teams with complementary expertise. Among these, two primary roles are commonly recognized: ***domain experts***, who provide essential domain-specific knowledge and offer innovative insights into disciplinary methods and advancements; and ***visualization experts***, who lead the design and implementation of visual representations and interactive systems. Additional collaborators, such as software engineers, data analysts, HCI specialists, and designers, may support particular aspects of the development process. Still, the iterative conversation between visualization and domain experts typically forms the backbone of a design study [23, 31].

While the formation of multidisciplinary teams has become both a trend and a foundational element of applied visualization research, the recognition and engagement of team members throughout the design process can vary. In problem-driven projects, the visualization literature often emphasizes a clear distinction between domain and visualization experts [41], advocating early role definition and alignment of expertise [23, 31]. However, recent studies have reported a growing blurring of boundaries between visualization and target domains, with collaborators increasingly taking on hybrid roles. In many cases, the roles and responsibilities of researchers evolve across time and can no longer be neatly categorized [13, 14]. This shift reflects a broader move toward more immersive and integrated forms of collaboration [10].

2.2 What Methods Guide the Process?

Visualization design study emphasizes solving real-world problems through close collaboration with domain experts [31]. Due to its inherently interdisciplinary nature, this research paradigm introduces challenges arising from differences in disciplinary knowledge, epistemologies, and cultural norms [2,6,21,23–25,31]. In response, the visualization community has developed a range of methodological frameworks and guidelines to support domain-driven and cross-disciplinary projects. These include process models [23,31,34], which offer structured, step-by-step procedures for conducting design studies; activity-centered approaches [21,24], which move beyond linear stages to emphasize the motivations and key activities of domain practice; and validation frameworks and evaluation practices [4,14,15,18,26,27,42], which aim to ensure methodological rigor and relevance. In addition, increasing attention has been directed toward the rigor of design processes [25], the types of contributions such studies generate [30], and the ethical considerations that emerge in collaborative settings [1,5].

Despite these advancements, tailored methodological guidance for specific domains remains limited. Community-led workshops such as VIS4DH (Visualization for the Digital Humanities) [37] and VISxAI (Visualization for AI Explainability) [38] have surfaced domain-specific concerns and fostered deeper dialogue between visualization researchers and domain experts. However, most of these efforts are concentrated within individual domains. A notable absence remains in comparative studies examining how domain characteristics shape visualization design practices across various fields. Systematic attempts to adapt or refine general design study guidelines to suit the needs of particular domains are still rare.

2.3 Do Domain Differences Matter?

The division between the sciences and the humanities – famously articulated by C.P. Snow as "The Two Cultures" [33] – continues to influence the organization of academic disciplines. Snow argued that scientific and literary intellectuals represent two distinct cultural groups, often struggle to communicate across disciplinary boundaries due to differences in thought styles, language, and epistemological assumptions. Scientific culture emphasizes quantification, generalizability, and predictive modeling, seeking truth through empirical validation and formal logic [3, 33]. In contrast, the humanistic tradition prioritizes interpretation, contextual meaning, and subjective understanding, aiming to capture the richness of human experience through narrative and reflection [3, 7]. These differences also affect modes of knowledge dissemination: scientific work is typically published in data-driven, methodologically rigorous formats, while humanities research favors open-ended argumentation and interpretive depth. Importantly, these boundaries are not fixed. Interdisciplinary fields such as digital humanities and science communication demonstrate how hybrid approaches can enrich scholarly inquiry.

In visualization research, domain differences have often been discussed through the lens of perceptual and cognitive variation, particularly regarding how users interpret and interact with visual representations. Prior work has shown that comprehension of visualization is affected by users' domain knowledge, data familiarity, and cognitive abilities [11, 17, 35, 43]. For example, Vázquez-Ingelmo et al. [39] found that domain expertise has a significant impact on how visualizations are interpreted. Visual literacy is crucial for effective data comprehension, underscoring the need for targeted educational interventions and design adaptations. However, much less attention has been paid to how these domain differences influence the collaborative dynamics of visualization design and development. Questions such as how disciplinary cultures shape expectations, decision-making styles, feedback practices, or design values remain underexplored.

3 Methodology and Approach

This interview study employed a qualitative approach, utilizing semi-structured interviews to gather insights from individuals involved in collaborative visualization projects across various domains and roles.

3.1 Participants

To capture a wide range of perspectives on collaborative practices, we recruited participants based on two criteria: their role in design studies and their domain of expertise. We identified three key roles:

- **Visualization Experts**: Researchers specializing in visualization, with expertise in designing and developing visual solutions.
- **Domain Experts**: Practitioners and experts from specific domains who hold domain knowledge and expertise.
- **Technical Experts**: Professionals with software engineering or data analysis backgrounds, responsible for the technical development and implementation of visualization systems.

Among the domain experts, we included individuals from three key areas: the applied sciences (including AI), the humanities, and the arts. Our participant pool consisted of 15 individuals: two visualization experts, two domain experts from the applied sciences, two from the humanities, three professionals from art-related fields, and four software engineers – two of whom were also AI researchers. Table 3.1 summarizes participants' domain of expertise, technical skills, and number of collaborative visualization projects participated in.

Table 1: Participant Background. *Indicates prior or current industry experience. *(Abbr.: nVis: Number of collaborative visualization projects participated; VIS – Visualization; HCI – Human–Computer Interaction; (R)SE – (Research) Software Engineering; AI – Artificial Intelligence; Appl. Sci. – Applied Sciences; NLP – Natural Language Processing.)*

#	Domain/Role	Skill & Background	nVis
P1	VIS	Scientific and Information Visualization	5+
P2	VIS	Visualization, AR/VR, HCI	5+
P3*	SE + AI	Software Testing, AI in Cybersecurity	1
P4	SE + AI	Machine Learning, Program Analysis	1
P5	AI + VIS	Explainable NLP, Visualization	1
P6	AI	Robotics, AI Planning, Explainable AI	2
P7	RSE	Visualization, Services Computing	5+
P8*	RSE	Geospatial Visualization, Data Science	5+
P9	Appl. Sci.	Statistics, Biology, Ecology	2
P10	Appl. Sci.	Geospatial Analysis, Urban Analytics	2
P11	Arts	Generative Art, Generative Media	5+
P12	Arts	Cognitive Art, Digital Experiences	2
P13*	Arts	Digital Creative Industries	5+
P14	Humanities	Political History, Digital Treaties	3
P15	Humanities	Medieval History, Early Printed Books	5+

We recruited participants using a combination of convenience sampling [8] and snowball sampling [28], targeting individuals with experience in collaborative visualization research. We first contacted professionals within our networks, then expanded recruitment through participant referrals.

3.2 Interview Structure

We conducted semi-structured interviews to elicit in-depth insights into participants' experiences in visualization design studies. Each interview followed a consistent structure, organized into four main sections to reflect the natural flow of the design process and collaboration.

3.2.1 Participant Background

This section aimed to break the ice and gain an understanding of the participants' backgrounds and prior experience with visualization tools and collaborative projects. Example prompts included:

- *What is your professional background and current role?*
- *Can you describe the project(s) where you collaborated with visualization researchers?*
- *How familiar are you with visualization techniques in your work?*

3.2.2 Domain Characteristics

Participants were asked to reflect on the nature of their domain and how its characteristics influence visualization practices. For those with cross-domain experience, comparisons were encouraged. Prompts addressed domain-specific workflows, data types, and tool expectations, such as:

- *What are the key features of your field, and what types of data and problems do you commonly work with?*
- *What visualization features and design considerations are particularly important in your domain?*

3.2.3 Design Study Process

This section examined participants' involvement across the design study's key stages, focusing on roles, practices, and challenges.

Domain Characterization & Problem Identification:

- *What was your role in defining the problem space?*
- *[For Domain Experts] To what extent did you feel your domain needs were understood by the visualization team?*
- *[For Visualization & Technical Experts] Have you noticed differences in practice when collaborating with experts from different domains?*

Collaborative Design & Implementation:

- *How were you involved in the co-design process, and to what extent?*
- *In what ways did your input influence design decisions?*

Evaluation & Testing:

- *What activities did you engage in to test and evaluate the tool? What were your contributions?*
- *How do you perceive the role of evaluation in the design process, and what are your expectations for it?*

3.2.4 Collaboration and Communication

The final section explored how collaborations were structured and perceived. Example prompts included:

- *How was collaboration structured in your projects with visualization researchers/domain experts?*
- *What aspects of the collaboration worked well or could be improved?*

3.3 Data Collection and Analysis

Each interview lasted between 60 and 90 minutes and was conducted in person or via video conferencing (Microsoft Teams). With participants' consent, all interviews were audio-recorded. Transcriptions were manually reviewed and served as the dataset for subsequent analysis. All responses were anonymized and assigned participant IDs (P1-P15). The study received ethics approval. Participants were informed of the study's purpose, data handling procedures, and their right to withdraw.

Coding Procedure Two researchers independently coded the transcripts. Codes were organized into three categories:

- ***Domain Characteristics:*** Perspectives on the defining features of participants' fields and comparisons with other domains. For domain experts, this included reflections on their own domain; for visualization researchers and technical experts, comparisons across multiple domains with which they had collaborated.
- ***Design Study Stages and Activities:*** Actions, practices, challenges, and expectations across design study stages, including problem identification, design and development, and evaluation.
- ***Collaboration Patterns:*** Reflections on interdisciplinary collaboration, including strengths, challenges, and suggestions for improving collaborative workflows.

Following independent coding, the researchers reconciled differences through discussion to finalize the coding and ensure consistency.

Thematic Analysis We conducted a thematic analysis to group codes into broader themes aligned with the interview topics:

- ***Domain- and Role-Specific Challenges***: Themes cited by multiple participants that highlight distinctive characteristics of particular domains or roles and their impact on visualization design.
- ***Within-Group Synthesis and Cross-Group Comparison Across Design Study Stages***: Aggregated perspectives from participants within the same domain or role group, and compared them across groups to examine differences and similarities in how various phases of the design study were perceived and approached.
- ***Collaborative Expectations***: Patterns related to interdisciplinary collaboration, including role distribution, coordination, and participants' expectations for effective design study workflows.

To contextualize the findings, we compared these themes across both domains and roles. This analysis revealed shared practices and domain- and role-specific challenges, illustrating how disciplinary contexts and team composition influence collaborative visualization design.

4 Results and Discussion

The interviews aimed to uncover domain-specific patterns and explore how these characteristics may influence the practices of visualization design studies. Before examining how domain factors affect various design stages, we first discussed how participants perceive their own domains and those of others. While such perceptions may be subjective – and at times stereotypical – they can shape collaboration dynamics.

4.1 Domain Characterization

Rather than characterizing domains in abstract terms, this section highlights how participants perceive and articulate disciplinary characteristics through their experiences in collaborative visualization design. We begin with the perspectives of visualization experts and software engineers who have collaborated across multiple disciplines, offering a cross-domain overview. This is followed by reflections from researchers in the humanities, arts, applied sciences, and artificial intelligence, who share domain-specific insights drawn from their own practice.

4.1.1 Perspectives from VIS Experts and SEs

Visualization researchers and software engineers in our study had experience collaborating across diverse disciplines, spanning humanities and scientific domains. A recurring theme in their responses was the contrast between hypothesis-driven and exploratory modes of inquiry.

VIS expert P1 highlighted an interesting shift in perspective when transitioning between collaborations in different domains: "*Scientists are very used to working with hypotheses [$\cdots$] but arts and humanities scholars may say, we have this belief that we can learn things by studying the data, not a specific hypothesis that can be evaluated as true or false.*" This remark captured a methodological contrast observed across disciplines: while scientific collaborations often begin with testable hypotheses, humanities scholars tend to adopt open-ended, exploratory inquiries aimed at constructing meaning through interpretation and contextual reasoning. Rather than evaluating truth claims, their work emphasizes narrative construction and emergent understanding. P2, P3, and P4 echoed this observation, describing differences in reasoning styles and problem framing between humanities and scientific domains.

While agreeing with the general contrast, P2 also observed that not all collaborations with scientific partners strictly follow a hypothesis-driven mode or begin with clearly defined problems. In several of his projects, particularly those involving domain researchers still exploring their data, he found that hypotheses often evolved iteratively as new insights emerged. This highlights that the distinction between exploratory and hypothesis-driven inquiry is not absolute but exists along a spectrum. Humanities disciplines may lean more toward exploratory approaches, while scientific fields are more likely to prioritize hypothesis testing; yet, in practice, both modes often coexist and inform one another across disciplinary boundaries.

Beyond differences in inquiry style, participants also emphasized how the distance, either at the domain level or in individuals' backgrounds, from computer science influences expectations around software implementation. Software engineer P3 noted that collaborators with engineering experience tend to better understand technical constraints, whereas humanities scholars or artists may sometimes underestimate the complexity of system development. This perceived asymmetry can result in mismatched assumptions about what is feasible or straightforward to build, underscoring the importance of early and explicit expectation-setting.

Participants also discussed broader disciplinary "cultures" that shape collaboration dynamics. For example, P2 described his experiences working with collaborators from various fields, noting differences in communication, management styles, and working norms. He characterized environmental scientists as "*nature-oriented and generally avoid extensive computer work*", medical professionals as "*procedural and following stringent requirements and rigid processes*", business experts as "*more outspoken and love discussing management and processes*", and cultural heritage scholars as "*enthusiastic storytellers*". Preferences were also perceived to be influenced by disciplinary background. As P3 noted, doctors often request minimalist, tap-based interfaces that require little configuration, while mathematicians and technically inclined users prefer systems that offer granular control and greater transparency. These preferences reflect deeper cognitive expectations of tool interaction – whether favoring interpretive freedom or analytic precision. Although anecdotal, such reflections suggest that disciplinary norms shape not only collaboration timelines and communication styles but also technical expectations and design priorities.

Taken together, these discussions reveal that visualization design is shaped by domain-specific cultures that go beyond the broad divide between the humanities and sciences. Participants' professional backgrounds, habitual workflows, and cognitive approaches all influence how collaboration unfolds from requirement analysis to co-design and implementation. Building on this perspective, we now turn to domain experts, exploring how they subjectively characterize their fields and the distinctive expectations they bring to the visualization design study.

4.1.2 Perspectives from Humanities Scholars

Humanities scholars highlighted the distinct epistemological foundations of their discipline compared to more technical domains. Their reflections foregrounded how disciplinary values, centered on narrative and contextual reasoning, shape both their research practices and their views on digital technologies and visualizations. For instance, P14 characterized history as: "*an old-fashioned discipline that emphasizes a narrative constructed from a deep connection with the subject matter, relying heavily on persuasion and inference.*" This statement reflects a common stance among humanities scholars: their work is grounded in contextual interpretation and argumentative reasoning, often embracing ambiguity, nuance, and multiple perspectives. In contrast, scientific disciplines tend to prioritize generalizable models and binary outcomes – approaches that may appear reductive from a humanities viewpoint.

Yet this contrast does not imply rejection of digital or computational tools. Rather, their adoption tends to follow a path of critical adaptation, as scholars balance disciplinary traditions with the affordances of emerging technologies. The growing prevalence of digital archives, computational methods, and visualization tools has introduced new practices; however, this shift is not solely driven by efficiency or convenience. It involves an ongoing negotiation between deep scholarly engagement and the pragmatic utility of digital tools. P15 reflected on this tension: "*The vast availability of digital archives has both facilitated and complicated historical research. While access to information has improved, the overwhelming volume of data and reliance on keyword searches can sometimes dilute the depth of scholarly arguments.*"

These perspectives partly align with the observations of visualization experts, reinforcing the methodological divide between the humanities and scientific domains. At the same time, they reveal a cautious but thoughtful engagement with digital methods: humanities scholars acknowledge the benefits of access and scalability, but remain concerned about potential losses in interpretive depth, methodological rigor, and historical context. Traditional, labor-intensive methods are still viewed as essential, offering immersion and analytical richness that automation alone cannot replace. This critical stance carries clear implications for visualization design. Tools need to strike a balance between efficiency and respect for disciplinary practices. In co-design and evaluation, attending to this balance is crucial for developing visualization systems that are not only usable but also epistemologically aligned with humanistic inquiry.

4.1.3 Perspectives from Artists

Participants with artistic backgrounds, whether from academia (P11, P12) or the creative industries (P13), emphasized the importance of artistic expression, aesthetic experience, and creative intent in visualization designs. In contrast to domains where visualization is primarily for analytical insight, artists viewed it as a medium for evoking emotion, engaging audiences, and exploring conceptual possibilities, as P11 described: "*Visualization becomes an interactive art piece where the audience's engagement directly influences the data representation and the project's outcome.*" This expressive orientation leads to fundamental differences in both team structure and design process compared to typical visualization design studies. In visualization art projects, instead of structured interactions among visualization researchers, domain experts, and technical developers, the design often involves a broader audience, sometimes the general public, as an integral part of the visualization experience. The process itself is treated as an artistic act, extending beyond the production of a final artifact. Unlike problem-driven design studies, where iterative refinement typically follows a structured framework akin to software development lifecycles, such methodologies may be less applicable in artistic contexts.

4.1.4 Perspectives from Applied Science and AI Researchers

Participants from applied science and AI backgrounds demonstrated enthusiasm for adopting visualization tools, particularly when they contribute to improved workflow efficiency. Given their work's inherent reliance on data analysis, they were generally familiar with visualization techniques and often used integrated visualization features within their workflows. Participants commonly noted that they possessed relevant knowledge in computer science, which made communication with visualization researchers relatively straightforward.

Reflecting on domain-specific working patterns, statistician P9, who had experience in multiple cross-disciplinary projects, emphasized the importance of generalizability in visualization tools. He argued that the most effective systems are those that can scale across different models and datasets, with an example: "*Researcher in my area will have their own models [⋯], it's perhaps easier to develop something that's specific to your model. But then, if you change the model or inputs, it can be more challenging to make it generalized.*" From the perspective of applied science and AI researchers, visualization is viewed as a natural extension of data analysis workflows. These researchers are generally receptive to new tools if they integrate well into existing pipelines. Their unique expectations center on practical functionality, particularly scalability, generalizability, and the ability to support complex data and model exploration.

4.1.5 Takeaways

Participants' reflections indicate that perceived domain characteristics, shaped by epistemological orientation, knowledge background, and research habits, influence collaboration dynamics, from team composition and problem framing to tool preferences and outcome expectations. Consequently, visualization design studies vary not only in topical focus but also in process structure. Collaborations with humanities scholars may involve extended periods of problem identification and exploratory dialogue, whereas projects with applied scientists tend to emphasize implementation and scalability testing. Viewed through the lens of the 'Nine-Stage Framework' [31], iteration in the precondition phase is typically more intensive in the humanities, while technical domains exhibit denser iteration in the core stages, particularly during implementation and evaluation. These contrasts underscore the need for process adaptations that align with domain-specific rhythms of engagement. Although the framework remains flexible for problem-driven studies, projects situated in artistic contexts may benefit more from the principles of participatory design [16] or participatory arts [29], which are better suited to open-ended creation and audience co-authorship.

4.2 Perspectives Across Design Study Stages: *Early Collaboration & Problem Framing*

In visualization design studies, the initial stage is critical for establishing a shared understanding of objectives, domain challenges, data availability, and technical constraints [31]. Close collaboration among visualization researchers, domain experts, and technical developers is crucial to ensure that all parties share aligned expectations. Rather than starting with predefined requirements, as in conventional software development, design studies often involve iterative exploration of domain problems, evolving use cases, and visualization designs. This exploratory nature demands that collaborators jointly refine both the problem space and design directions as the project unfolds. In this section, we examine this early phase from the perspectives of three key collaborator groups: visualization experts, software engineers, and domain experts. We highlight similarities and differences in their practices during initial problem framing and their varying expectations for building mutual understanding.

4.2.1 From the Visualization Researchers' Point of View

Visualization researchers in our study observed that domain collaborators do not always enter projects with clearly defined needs. Early collaboration was often described as an exploratory process in which problems and goals gradually emerged through dialogue and iteration. They also emphasized their role in guiding domain experts, particularly those unfamiliar with visualization or unsure of their initial needs. When domain experts asked questions such as, "*We don't know what's possible, can you show us some options?*", visualization researchers often took the lead in shaping the problem space by proposing possibilities and eliciting feedback to support requirement specification. Regarding how visualization experts uncover implicit domain goals, both P1 and P2 emphasized the importance of asking targeted questions, such as the purpose of data collection or core research questions in their field. Understanding domain experts' workflows and tools was also crucial. Beyond discussion-based methods, they noted the value of observational sessions and hands-on interactions in revealing domain challenges. P2 also stressed the need to involve real data early in the collaboration, stating: "*To see their data, discuss it extensively, and conduct meetings where examples are shown, helps in establishing what's possible.*" Both participants reinforced that the initial phase is inherently iterative, involving multiple rounds of interaction between visualization researchers and domain experts helps not only to specify the problem or understand the data, but also to build mutual trust.

These reflections highlight how problem identification unfolds during the early stages of collaboration. While no explicit domain distinctions were made, P1 and P2's accounts suggest two common scenarios.

The first and more straightforward scenario involves domain experts who have a relatively clear goal and an understanding of how visualization can support their work. In such cases, collaboration typically begins with a set of well-defined requirements, followed by feedback from visualization researchers regarding feasibility, limitations (e.g., technical constraints, data privacy, or cost), and potential refinements, before proceeding to co-design and implementation.

Most collaborations instead involve domain experts unsure how visualization could aid their workflow. This ambiguity stems from either: 1) limited familiarity with visualization's potential – they understand their domain problem but are unsure how visualization applies; or 2) a more abstract case where the problem itself is loosely defined, and the role of visualization remains speculative.

These divergent starting points call for different strategies. Collaboration can proceed efficiently in requirement-driven cases through a few iterations of feasibility analysis and visual task refinement. However, for more ambiguous scenarios, additional effort is needed to surface actionable needs. Visualization researchers often serve as intermediaries, helping bridge the gap between domain challenges and possible visualization solutions [19, 32]. Early-stage workshops or exploratory meetings are instrumental in these situations. Introducing visualization techniques from similar contexts and demonstrating concrete examples can help domain experts conceptualize what is possible. When the problem is unclear, deeper engagement – like exploring research questions and workflows – helps reveal useful visualization entry points.

4.2.2 From the Developer's Point of View

Participants (P3, P4, P7, P8) reflected on their experiences as developers in design studies. Although some currently work in research, some had prior industry experience as software engineers. This background shaped their reflections, often prompting comparisons between research-oriented visualization projects and structured product development workflows. From their perspective, design studies often lack the upfront planning typical of engineering processes. Unlike traditional software development, where technical specifications, infrastructure constraints, and feasibility assessments are defined early on, design studies often begin in a more open-ended manner. Developers noted that this exploratory nature, while necessary for research, can introduce challenges during implementation, especially when they join after key design decisions have been made. Without access to upstream discussions, they may face ambiguous or shifting requirements or lack context for why specific directions were chosen. They also emphasized the benefits of surfacing technical conditions early.

These reflections highlight the need to accommodate differing expectations among collaborators. Although visualization researchers often engage in iterative and flexible design processes, developers tend to prefer clearer structures and defined inputs. This contrast can lead to misalignment, especially when developers are not involved in early design discussions. Role boundaries, however, are fluid. In some collaborations, no technical personnel are involved, and visualization researchers assume development responsibilities, thereby bridging the gap between design and implementation. In others, developers are brought in later, with limited visibility into initial decisions. In such cases, bridging the gap requires communication strategies that take into account both the evolving nature of research and the practical constraints of implementation. When early developer involvement is not feasible – a common reality in research settings, visualization researchers with technical expertise need to serve as liaisons, translating design goals into implementable components. Even brief early consultations with technical collaborators can help surface feasibility concerns and align expectations. Based on these reflections, we conclude with several communication-oriented considerations to support alignment among collaborators in design studies:

- *Surface implementation constraints early, such as data availability, privacy, scalability, and deployment limitations.*
- *Translate domain input into a preliminary set of core functionalities, while explicitly communicating that both features and goals may evolve throughout the project.*
- *Discuss early on what the system is intended to be – whether a lightweight prototype, an interactive demonstrator, or a long-term tool requiring ongoing maintenance.*

These practices are not rigid prescriptions, but flexible prompts for reflection and alignment. In research-driven visualization projects, where change and exploration are inherent, fostering mutual understanding across roles is often more valuable than striving for premature certainty.

4.2.3 From the Domain Experts' Point of View

Domain experts from diverse backgrounds consistently described their primary role in the early phase of collaboration as explaining domain knowledge and articulating real-world challenges. They emphasized that successful collaboration depends on building shared understanding from the outset. This often requires considerable effort to communicate domain-specific concepts, use cases, and data nuances in ways that are accessible to collaborators from other disciplines.

Participants with humanities backgrounds noted that such understanding is best developed through example-driven dialogue and iterative clarification, especially when disciplinary assumptions differ. P15 reflected on the importance of clarity when communicating domain knowledge, noting that what seems obvious to them may not be evident to those outside their field. She emphasized that it is crucial to "*give absolute clarity on every step and also explain why they need those steps and what they achieve*" when working with scientists.

Discussion extended beyond the specific actions domain experts took during the early stages, touching on their emotional experiences and expectations regarding collaborators' engagement. Humanities researcher P14 shared his reflections on articulating domain challenges and co-developing initial design solutions. His experience, to some extent, echoed the impressions that visualization researchers often hold about humanities-focused projects or collaborators – namely, that they lack technical knowledge or struggle to articulate needs in ways aligned with visualization design. These perceptions, though often unintentional, can lead to interactions where domain insights are insufficiently trusted or overly simplified. At the same time, they may result in emotional discomfort, drawing attention to the "matters of care" in design studies [1]. As P14 reflected: "*There's often this moment when they (visualization experts) feel the need to take you to a very basic articulation of what you're trying to achieve. I've found this approach occasionally useful, but at times also frustrating. Sometimes I feel that they don't necessarily trust our instincts about what would be useful.*"

In contrast to humanities scholars, domain experts in applied sciences and AI did not describe the same level of effort in articulating domain knowledge. Still, they did acknowledge challenges related to ambiguous terminology. To address this, P6 emphasized the importance of timely clarification and calibration, particularly when the same terms may carry different meanings across communities.

In art-focused projects, collaboration often follows a different trajectory from those in scientific or humanities domains. These initiatives prioritize audience engagement, creative expression, and experiential storytelling over problem-solving or data analysis. According to P13, such projects frequently begin with either unconventional datasets or no data at all. Rather than viewing data scarcity as a limitation, artists often treat it as a narrative and design opportunity, shifting the focus from analytical insight to conceptual provocation and participatory experience. Collaboration in these settings is not limited to visualization researchers, artists, designers, and data providers. Still, it often extends to the public, who may contribute their own experiences and interpretations during the visualization process. This approach repositions visualization not as a static representation of data, but as a generative platform for co-creating meaning. The goal is not to present predefined problems and insights, but to create spaces for reflection, conversation, and collaborative authorship. As P13 described, the early phase is about "*creating a platform for the public to contribute their experiences, thereby building new databases in real time that narrate the story.*"

Across domains, participants consistently described early collaboration as a phase focused on making domain knowledge accessible to visualization researchers. While strategies such as clarification, calibration, exemplification, and contextual explanation were used, their forms varied across disciplines. Notably, humanities scholars emphasized articulating domain goals through situated activities – an approach aligned with principles from action research [12, 20] and activity theory [40]. These perspectives suggest that visualization researchers can adopt such principles as conceptual prompts during early-stage inquiry, using real-world practices as entry points to elicit domain goals in ways that complement process models like the 'Nine-Stage Framework' [31].

4.2.4 Takeaways

Participants' reflections revealed differing goals and expectations during early-stage collaboration, shaped by both disciplinary distance and collaborator roles. In problem-driven domains such as applied sciences and the humanities, early efforts typically focus on exchanging domain knowledge and identifying visualization-relevant problems. Design study frameworks like [31] are well suited to such collaborations, yet participants noted that greater time and effort are often needed when working with domains that are epistemologically distant from visualization or computer science. Art-focused projects diverge further, prioritizing participation and creative exploration over structured problem formulation, thus challenging the applicability of conventional design study models. Although goals in the early phase may differ across collaborators' roles, participants emphasized a shared priority: building mutual understanding, both cognitive and affective. For visualization researchers, who often lead or mediate the process, this entails navigating not only disciplinary differences in domain knowledge transfer but also role-specific expectations, such as supporting developers through early clarification of technical constraints, and fostering a respectful, inclusive environment where domain experts, particularly from the humanities or arts, feel their perspectives are understood and valued. Based on these reflections, we outline the following considerations for visualization researchers during the early stages of a design study:

- Allow more time and effort in epistemologically distant domains such as the humanities, where domain goals often emerge through exploratory dialogue. Approaches grounded in activity theory and action research can help uncover implicit needs and align expectations more effectively. Presenting visualization examples can also help domain experts form a clearer understanding of what visualization can offer.
- Avoid overestimating alignment in epistemologically close domains. In fields such as applied sciences and AI, a shared technical language may mask subtle conceptual differences. Early and ongoing clarification of terminology and assumptions remains essential.
- Foster inclusive, early-stage collaboration across roles and disciplines. Engage technical collaborators early to surface implementation constraints and feasibility considerations, especially when they are not involved in the design process. At the same time, cultivate emotional trust and epistemic humility by creating respectful environments in which collaborators feel their intuitions and contributions are heard and meaningfully reflected in design directions.

4.3 Perspectives Across Design Study Stages: *Co-Design & Implementation*

The collaborative design and implementation process across different application domains typically follows a cycle of prototyping, feedback, and refinement, though art-related projects may take a different path. While stakeholder expectations generally align around incremental refinement, practical limitations, such as time and funding, can restrict the frequency of iteration and the depth of reflective discussion. Interview insights reveal broad support across all participant groups for iterative, collaborative practices. However, actual levels of involvement vary. In this section, we present perspectives from different collaborator roles to illustrate how they navigate the co-design and implementation process.

Visualization researchers described sketching and low-fidelity prototyping, often involving little to no programming, as effective strategies, particularly during early-stage ideation. Aligned with the 'Nine-Stage Framework' [31], this approach enables rapid trial and error through combined verbal and visual expression, facilitating clearer communication of abstract ideas. P2 noted that such artifacts are especially valuable when collaborating with domain experts from epistemologically distant fields, who may have well-formed design intuitions but lack the technical vocabulary to articulate them: "*They had this idea of this kind of graph in their mind, but they weren't sure how to articulate it in technical terms.*" Letting domain experts "take the pen" to sketch their concepts, followed by feedback from visualization researchers and developers, was seen as a productive, inclusive design pattern.

From the developers' perspective, feasibility remained a central concern during co-design and implementation. Both P3 and P7 emphasized the importance of prioritizing core features when resources are limited, noting that domain collaborators often request more than can realistically be implemented. They also pointed out that many usability-related requests, such as explanatory tooltips, tutorial pages, or aesthetic adjustments, can be deferred until later stages of development. As P8 suggested, postponing these secondary refinements until the core functionality is established is a pragmatic strategy that developers hope collaborators will consider.

Participants from applied sciences and AI generally found the iterative process of incremental development and refinement intuitive and engaging. They described co-design interactions, especially those involving visual suggestions from visualization experts about suitable chart types, as straightforward to follow.

Compared to applied science and engineering domains, humanities projects often involve more iterative engagement during co-design. This extended involvement supports shared knowledge building, deepens visualization understanding, and enables comparison across alternative solutions. While humanities researchers valued iteration, they emphasized that their involvement could take different forms. P14 reflected on two modes he had experienced: 1) when he had a clear vision of the desired outcome, he engaged closely in design discussions, contributing to intensive iteration; 2) when the problem was more abstract, he preferred a parallel approach – articulating domain needs early, then stepping back to let the visualization team explore possible solutions, before re-engaging at the evaluation stage. He noted that continuous, high-frequency interaction was not always necessary; what mattered was flexibility and responsiveness to the problem context.

Artists in our study offered perspectives unique to creative domains. Extending from their accounts of early-stage collaboration, they described the design process as a shared and exploratory journey, echoing the "design by immersion" approach [10], where disciplinary boundaries and role distinctions are softened to foster inclusive and personally meaningful knowledge-making. Besides their co-design practices, artists also reflected on relational and communicative challenges during implementation. P12 emphasized that artists often bring forward quite visionary ideas that are not always grounded in a clear understanding of what is technically feasible. In such situations, she stressed the importance of care-oriented collaboration, where developers respond not with outright rejection, but with constructive alternatives: "*It's most helpful when someone, instead of just saying 'you can't do that,' offers an alternative that might achieve the goal differently.*" To bridge gaps in communicating nuanced artistic intent, artists often take initiative themselves – creating hand-drawn sketches or learning prototyping tools like P5 or D3 to express their ideas more concretely. These efforts provide shared reference points for discussion and help translate creative vision into implementable forms.

Takeaways

Reflections from participants across roles and domains reveal that iterative, agile-inspired design practices remain widely appreciated and engaging in co-design and implementation phases. However, depending on the disciplinary background and nature of the project, more user-centered or immersive approaches may be needed, requiring flexibility in structuring co-design activities. When disciplinary distance or technical gaps exist, building mutual understanding remains central, best supported by both responsive collaboration and mutual initiative. For visualization researchers, this means designing co-design activities that enhance collaborator involvement, for example, inviting them to sketch out ideas rather than only describe them verbally, or offering lightweight tool introductions to support hands-on experimentation where appropriate. Another strategy involves combining iterative and parallel prototyping: when domain experts cannot engage continuously, visualization teams can explore multiple design directions and later present them in focused feedback sessions, ensuring sustained progress and richer collaborative input.

4.4 Perspectives Across Design Study Stages: *Evaluation Activities & Iterative Reflection*

Evaluating the effectiveness of collaboratively developed visualization tools typically involves a mix of formal and informal activities. Insights from the interviews suggest that visualization researchers frequently lead the planning and guidance of evaluations to ensure alignment with project goals and user needs. Common practices mentioned by interviewees can be categorized into two main approaches:

- **Iterative Feedback:** Involves informal, ongoing feedback loops through regular meetings. Domain collaborators provide comments that help refine and improve the tool. These sessions are often qualitative, relying on real-time discussion.
- **Structured Evaluation Sessions:** Designed to gather deeper insights using formal protocols (e.g., usability tasks, surveys, or interviews), these sessions often engage a wider range of users to evaluate tool functionality, usability, and generalizability.

Visualization experts emphasized that it is crucial to pay close attention to how domain experts react and respond when carrying out evaluations, whether through iterative discussions in a more informal manner or a structured approach. P1 and P2 noted that domain experts sometimes provide subtle, non-explicit feedback that can be easily overlooked: "*When a domain expert does give any kind of reaction, they rarely explain, they might say something like 'Oh, that's interesting!'* " Digging deeper into the reasons behind simple praise or expressions of disfavor is important. Visualization researchers should employ strategies that encourage deeper reflection before such observations are lost. This can involve prompting immediate elaboration or reintroducing prior remarks for further discussion if immediate follow-up is not feasible. When feedback remains vague, making evaluation more tangible, such as by asking domain experts to compare different versions or alternatives, can help reveal specific preferences.

While visualization researchers shared more strategies for eliciting 'useful' feedback, domain collaborators described their experiences more during the evaluation. A common challenge they highlighted (P6, P9, P15) was the learning curve associated with unfamiliar interfaces. As P15 noted: "*When you're presented with an interface that you can click everywhere, it can be a bit overwhelming sometimes.*" This issue is especially pronounced when evaluating with users who were not involved in the system's development. To mitigate this, participants emphasized the value of onboarding activities before conducting the evaluation, such as walkthroughs and tutorials, to reduce cognitive load. Task-oriented evaluations were also perceived as helpful, as they provided clearer expectations and elicited more focused feedback.

At the same time, humanities researchers highlighted how differences in visualization literacy affected their interpretation of design choices. P15 recounted how certain visual forms, such as Chord diagrams, felt intuitive to visualization researchers but were challenging for her and her colleagues. She contrasted this with a Heatmap design that initially seemed confusing to her but later revealed historical trends she found insightful. Such experiences illustrate how preferences can shift as domain experts gradually become more familiar with visualization techniques over the course of a project. This gradual increase in literacy raises a deeper consideration: how does evolving expertise shape evaluation? As domain experts become better equipped to interpret complex visual representations, their feedback can shift from early impressions to more informed critiques. This reinforces the value of involving domain collaborators throughout the design process, rather than relying solely on end-stage evaluations. Long-term engagement and iterative reflection enable visualization solutions to be refined in tandem with the collaborator's evolving understanding.

However, this progression introduces tension. While increased literacy benefits involved collaborators, the final tools are often meant for a broader audience. If design decisions are overly shaped by highly engaged participants, they may not align with the needs of less-involved users. Addressing this requires attention to general usability. As mentioned earlier, thoughtful onboarding is essential – not only through interface walkthroughs, but also by embedding foundational visualization concepts and design rationales to support basic visual literacy. Additionally, lightweight interventions during the design process, such as short surveys or feedback forms distributed by domain collaborators to their peers, can help capture wider community perspectives and ensure design decisions remain inclusive.

Researchers in AI-related domains described evaluation practices that follow non-traditional testing and feedback collection methods. Due to the fast-paced development culture and widespread technical fluency within the AI community, many practitioners, often with computer science backgrounds, are comfortable engaging with tools through open-source workflows. P4 explained: "*We release our source code and the developed tool simultaneously with or soon after the submission of our paper, allowing the public and reviewers to comment.*" This practice allows for broader, community-driven evaluation beyond formal studies. While the open-source principle, where anyone can test and contribute, provides an ideal approach for evaluation and maintenance, it also sets higher bars for user proficiency compared to traditional user studies. Therefore, it may not be easily transferable to other domains, where end users may lack the technical expertise required for effective participation in the evaluation process.

Takeaways

Across domains, most collaborators expressed a preference for informal, dialog-based evaluation over structured studies, mentioning them as more time-efficient, less stressful, and equally insightful, especially when collaborators are closely involved throughout the project. Structured evaluations, while valuable, often require domain experts to help recruit broader users, adding organizational burden that may deter their enthusiasm. These preferences echo broader debates in the visualization community around the value and trade-offs of formal versus informal evaluation [36]. In domains with limited overlap with visualization, such as the humanities, sustained collaboration fosters gradual literacy gains, enabling more nuanced and informed feedback. While this benefits from iterative co-design, it may also introduce preference bias between deeply involved collaborators and the broader user community. When conducting design studies in such contexts, visualization researchers should proactively plan for extended iteration and evaluation. This includes anticipating the effort needed for both informal and structured assessments, initiating early conversations with domain collaborators about the feasibility of mid-project evaluations involving broader user groups, and considering the potential need for visualization literacy tutorials to support later adoption.

4.5 Insights on Collaborative Efforts

This section presents key reflections that extend beyond specific design stages, offering a broader perspective on recurring challenges encountered during collaborations. Recognizing these challenges early can help mitigate friction and support smoother project development.

4.5.1 Challenge of Assembling Multi-Skilled Teams

Visualization projects require a blend of expertise – from software engineering and visualization design to data science and domain-specific knowledge. Since few individuals possess the full range of skills, assembling interdisciplinary teams with diverse competencies is often necessary. Yet even within such teams, knowledge gaps frequently emerge. Occasionally, domain collaborators with prior visualization experience can serve as effective bridges between disciplines. For example, P15 described helping domain colleagues get familiar with visualization tools and translating domain knowledge into more accessible language for visualization researchers. However, such cases remain exceptions. When collaborators participate in a design study for the first time, these gaps become more apparent. P1 reflected on the often-overlooked impact of training needs, particularly in equipping collaborators with the foundational skills required for a design study, especially when they are less familiar with or come from domains less accustomed to visualization research. He emphasized that: "*Finding individuals with expertise in all these areas is extremely difficult, often necessitating extensive training. This, in turn, prolongs the development process, a factor frequently underestimated by domain experts.*" Importantly, training needs may arise even within one's own domain. Not every domain expert is immediately comfortable with the specific data, tools, or practices used in a given project. In this light, training delays should be anticipated rather than treated as exceptions. Successful collaboration depends not only on assembling a balanced team but also on recognizing learning as an ongoing, bidirectional process throughout the project.

4.5.2 Challenge of Building Common Ground

Multidisciplinary teams often bring divergent ways of thinking, priorities, and skill sets, which can complicate mutual understanding. Beyond the previously discussed need for training to prepare all parties for a design study, visualization researchers P1, P2, and software engineer P3, noted that building common ground around collaborators' priorities, preferences, and intentions is itself a significant challenge. They emphasized the value of early and sustained "calibration conversations" to align expectations and prevent miscommunication.

Beyond conversations, efforts to adopt or experience each other's workflows and tools can also help build a shared understanding. As mentioned earlier, artist P12 has experience handling programming herself to ensure that the artistic vision is not compromised. While such efforts are commendable, they can also be highly demanding. Gaining familiarity with another collaborator's tools, workflows, or ways of thinking often requires a substantial amount of time and effort. While such efforts are valuable, they are also resource-intensive. Gaining familiarity with another collaborator's practices or mindset requires time, energy, and often a willingness to stretch beyond one's comfort zone. These efforts can bridge disciplinary divides and help preserve key project values, but they are not always feasible, nor equally distributed across roles. Ultimately, building common ground is not about erasing disciplinary distinctions, but about fostering mutual respect, adapting communication styles, and remaining open to deep cross-boundary engagement, even when that effort is considerable.

4.5.3 Challenge of Potential Conflicting Motivations and Goals

Even with shared project aims, collaborators may hold different motivations. Misalignments may arise due to asymmetric payoffs, disciplinary norms, or divergent expectations. Akbaba et al. identify several forms of power asymmetry in design studies [1], highlighting two key concerns: 1) Domain experts invest significant time and communication effort during the collaboration, only to receive a visualization prototype that lacks long-term support, deployment, or maintenance. 2) Visualization teams sometimes pursue research goals that are misaligned with domain needs, particularly when the problem at hand does not offer opportunities for visualization novelty.

Visualization researchers in our study expressed concerns about being perceived primarily as service providers. P2 described moments when collaborations felt unbalanced, emphasizing the value of shared innovation: "*We often tend to serve other domains. [$\cdots$] Sometimes the discussion shifts toward more practical matters, like 'can you develop it for us?' [$\cdots$] But if there's something from the visualization point of view, an opportunity to explore or innovate, then that's really awesome because both parties can innovate.*"

Further tensions may arise when involving developers, particularly those with industry experience who are accustomed to structured workflows, as discussed in Section 4.2.2. For engineers, implementation planning, deployment logistics, and long-term maintainability are natural priorities. However, in exploratory design studies, such aspects often emerge late in the process, which can create friction when expectations are not aligned early on.

Tensions also emerge in evaluation practices. As noted in Section 4.3, domain experts favor flexible, informal evaluation over structured studies. P14 acknowledged the limited value of formal user studies for his own purposes, but expressed a willingness to accommodate both perspectives: "*I understand the need for structured feedback within the visualization community, I personally find it less useful and strive to accommodate both needs to ensure successful collaboration.*"

These examples highlight broader structural dynamics that shape collaborative visualization projects, particularly how norms within the visualization community, including publication and review practices, influence project priorities. In domain application visualization research, the emphasis on novelty remains a prevalent criterion for publication, despite existing literature that acknowledges multiple forms of contribution in design studies [30, 31]. A similar trend is also observed in the preference for formal summative evaluations over informal, discussion-based feedback. As discovered in [42], formal evaluations remain widely adopted and frequently reported in papers published in high-impact venues. While this supports rigor and standardization, it may also discourage alternative forms of evaluation. This reflection is not a critique of existing standards, but an invitation to acknowledge the diverse contributions of domain-focused visualization research. Expanding recognition beyond novelty and formal evaluation could reduce collaboration tensions and promote more inclusive practices.

4.5.4 Challenge of Limited Time and Resources

When collaborators have limited time or cannot commit to long-term involvement, full design studies may not be feasible. As P2 noted, when needs are immediate or data is already finalized, teams often adopt a more ad hoc approach, which "*while not ideal, still yields valuable insights and outputs.*" While design studies remain foundational, adapted processes that fall short of full design study criteria, often due to time or resource limitations, can still yield valuable contributions to visualization practice [34].

4.5.5 Takeaways

Interviewees' expectations for effective collaboration offer guidance on cultivating productive and resilient partnerships in design studies.

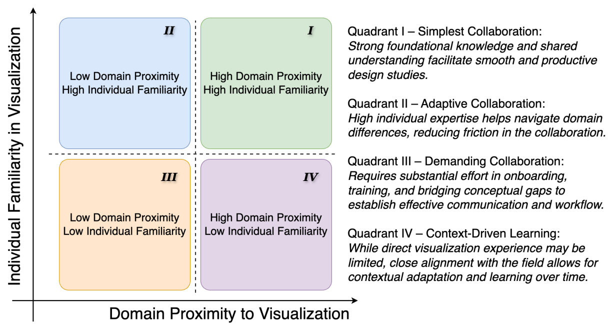

Fig. 1: This figure illustrates the relationship between domain proximity and the collaborator's familiarity across four quadrants.

Shared Motivation and Active Engagement Successful visualization collaborations hinge on mutual commitment and a shared sense of purpose. Visualization researchers especially value domain collaborators who recognize the potential of visualization and are motivated to remain actively engaged throughout the process. As P1 observed, collaborating with someone who regards visualization as a scientific discipline fosters more productive exchanges and enables meaningful innovation from both sides. A lack of engagement or unwillingness to explore visualization possibilities can lead to shallow iterations. Early project phases should focus on identifying collaborators who need visualization and believe in its value. Over time, maintaining engagement requires reciprocal effort: domain experts must offer input, and visualization teams must act on it. Each visible improvement reinforces the collaborative loop, encouraging deeper commitment.

Planning with Multidisciplinary Awareness Beyond engagement, effective collaboration depends on careful planning and sensitivity to diverse disciplinary norms. Collaborators with composite backgrounds can help bridge methodological gaps, better anticipate conflicting expectations, and support long-term sustainability. However, such liaisons are not always available. In their absence, early alignment becomes crucial. Initial all-hands meetings can surface each party's goals, constraints, and potential trade-offs. When knowledge or skill gaps exist, whether within or across domains, mutual onboarding or lightweight training may be necessary. Recognizing these asymmetries early allows teams to anticipate delays, share responsibilities more equitably, and lay the foundation for sustained collaboration.

Divergent Thinking and Visualization Openness Differences in disciplinary thinking and comfort with visualization can present challenges in co-design. These divergences act as boundary objects that shape collaborative dynamics and influence design. Visualization researchers noted that artists often approach problems more abstractly (P2), while openness and readiness to visualization among domain experts varied with familiarity and mindset (P1). Tailoring engagement strategies to collaborators' backgrounds and thinking styles helps accommodate differing levels of visualization fluency. While general design study frameworks remain central to problem-driven research, a greater domain distance often requires a longer ramp-up, more reflective iteration, and additional training. Adjusting time and methods can boost understanding and outcomes.

5 Reflections

Our investigation reveals that disciplinary differences (cognitive approaches, inquiry styles, and value systems) shape the way design studies unfold. These fundamental distinctions influence collaboration practices, expectations, and thinking across all stages of a design study.

While domain traits set the context, collaborative success also depends on individuals. Personal familiarity with visualization often matters as much as disciplinary proximity. To conceptualize this interplay, we introduce a model (Fig. 1) that maps collaboration readiness along two axes: domain proximity to visualization and individual familiarity with visualization tools and thinking. This yields four scenarios:

Quadrant I: When both metrics are closely aligned with visualization and computer science, collaboration tends to proceed smoothly, particularly in early stages, supported by shared knowledge and motivations. Teams can capitalize on this alignment to focus on iterative design, rapid and parallel prototyping, and exploration of novel visualization techniques tailored to domain needs, along with experiments on scalability and generalizability.

Quadrant II: When the domain is distant from visualization and computer science, but the collaborator is technically proficient and enthusiastic about visualization, this enthusiasm can help bridge disciplinary gaps. Such collaborators often serve as liaisons between their domain and visualization experts, making this an ideal setting for developing tailored visual solutions that enhance domain-specific workflows. Over time, this can increase the impact of visualization within the field. In the early stages, the collaborator can help communicate domain context, research challenges, and visualization-relevant needs in accessible ways, supporting a deeper mutual understanding. However, as these collaborators are more engaged and visualization-aware than the average domain user, there is a risk that their feedback may not fully represent the broader community. When conducting design studies in such contexts, it is crucial to remain aware of these differences. Mid-project interventions, such as lightweight surveys with additional domain users, can help surface contrasting perspectives and improve the inclusivity of the resulting designs.

Quadrant III: Though less common, scenarios where the domain is closely aligned with visualization and computer science, but the collaborator lacks familiarity with these fields, present unique challenges. Visualization researchers may have a general understanding of domain challenges and potential visual solutions, but these hypotheses must be validated and aligned with the domain collaborator's perspective. In such cases, early-stage collaboration should include training sessions to bridge the visualization knowledge gap and ensure a common foundation. When possible, involving additional domain practitioners with greater visualization experience in initial discussions and iterative testing can help surface misalignments and mitigate bias, ensuring that designs remain grounded in broader domain needs.

Quadrant IV: When both the domain and the collaborator's expertise are distant from visualization and computer science, collaborations typically require longer timelines and sustained commitment. Domains with limited exposure to visualization may benefit from its integration, revealing new use cases and previously unrecognized analytical opportunities. However, establishing trust, fostering acceptance, and developing procedural knowledge cannot be achieved overnight. It requires gradual trust-building, learning, and stepwise integration of visualization into domain workflows. Progress in the early stages may be slow. However, once a visualization solution successfully addresses a domain-specific challenge, it paves the way for further advancements, allowing for a deeper exploration of additional problems. This iterative expansion increases the likelihood of impactful and transformative visualization breakthroughs.

Recognizing and preparing for these scenarios can pave the way to design studies, ensuring that the planned processes are tailored to both the domain's needs and the readiness of individual collaborators.

6 Limitations and Conclusion

This study explored how domain-specific characteristics shape collaborative visualization research, drawing on perspectives from domain experts, visualization researchers, and developers. Our findings indicate that differences in epistemologies, workflows, and familiarity with visualization affect expectations and practices across the various stages of the design study. Although the interviews provided diverse information, the sample remains limited in scale and representation. Participants' experiences may reflect specific collaboration contexts rather than general patterns. Future work could expand the participant base, explore emerging domains, and examine collaborations over longer timeframes or at different stages of maturity. Despite these limitations, the study offers a grounded understanding of how disciplinary distance and individual experience jointly shape the trajectory of visualization collaborations. We hope these reflections support visualization researchers in anticipating collaboration dynamics, tailoring their methods, and fostering more inclusive, context-aware design studies.

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