

Embedding visual thinking into an AI-driven furniture design critiquing system

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Abstract

The *critique* is a cornerstone of design and arts education. In furniture design, the critique often takes the form of formal critique—an isolated exercise aimed at developing tacit formal awareness. However, in the landscape of AI-driven solutions for designers, content generation dominates over sensemaking and current critiquing systems remain ill-equipped due to their inability to sense, adapt, and question meaningfully. In this paper, we present fCrit, a critiquing chatbot that collaborates with human designers to reflect on the visual forms of furniture designs. Our work involved reconstructing the process behind enabling AI to analyze visual concepts and patterns using a hand-crafted expert knowledge base, and developing a functional, critique-ready prototype. We envision a critiquing chatbot that resonates with human creativity and empowers designers in form-finding. This work-in-progress is part of a broader initiative that aims to demonstrate how Human-Centred Explainable AI solutions can support creativity for artists and designers.

Introduction

In design education, the transformation of tacit knowledge into actionable insights is what the *critique* is all about. Critiquing is a craft that has always been associated with human sensibility, experience, and empathy (Goldschmidt, 2002). It is an essential practicum for pedagogical (Boyer and Mitgang, 1996; Schön, 1992a) and professional settings (Dreyfuss, 1955). To aid this process, *critiquing systems* emerged as a computer-aided design tool that assists human designers in making and analyzing design decisions by providing feedback (Robbins and Redmiles, 2000; Silverman, 1992).

We are motivated by the recent advent of generative AI in the design process, particularly regarding how designers engage with critique—the problem framing component of design thinking. The majority of generative AI solutions for designers prioritize content generation over other aspects of design sensemaking such as discovering, training, or testing (Shi et al., 2023). However, this generation-focused trend propels the fixation effect on designers (Wadinambiarachchi et al., 2024), impeding the critical and divergent aspects of design thinking. Furthermore, existing critiquing systems fall short for creativity support in furniture design due to their narrow and homogenizing feedback (Oh and

Oh, 2017). These systems treat expert knowledge as a prescriptive rubric to distinguish right from wrong to identify improvements. This approach is not suitable for critiquing visual form as it prioritizes expert knowledge over creative spark (Goldschmidt, 2003). And because furniture design critiquing is both subjective and grounded in visual theory, it specifically necessitates a critiquing modality that honors both the *interpretive* and *formal-awareness* aspects of furniture design. Our research scope focuses primarily on these dimensions of critique.

In this paper, we propose fCrit, an AI-driven critiquing system for visual form of furniture design. fCrit counters the aforementioned shortcomings by embodying a pedagogical framework that facilitates formal insight discovery rather than error diagnosis, harnessing the creative potential of studio critique while providing the convenience of a personal support system. We present two main contributions: (1) a methodology for embedding design expert knowledge as a structured knowledge base, and (2) a prototype for fCrit with a multi-agent architecture that utilizes this knowledge base. In the next section, we provide references to related work in the areas of critiquing systems, AI-driven tutoring systems, and design learning, followed by the theoretical framework that supports the development of fCrit. We then detail the architecture, components and pipeline used in our system and we elaborate on our structured knowledge base—our first contribution. Finally, we present an interaction with dialogue results that demonstrate the system in action—our second contribution. We conclude the paper with our future work and a reflection on the implications for AI-driven design learning systems.

Related Work

Critiquing systems are computer-aided design tools that evaluate design solutions and support designers' task performance (Robbins and Redmiles, 2000; Silverman, 1992). These systems typically include an analyzer module that compares user input to a reference knowledge base, and a dialogue module that identifies errors (Silverman, 1992).

Despite broad adoption in domains ranging from design sketching (Oh, Do, and Gross, 2004) to architectural layout planning (Chun and Ming-Kit Lai, 1997; Woodbury and Drogemuller, 2000), these systems often overlook critical aspects of creativity support. Key considerations include



Figure 1: Gebrüder Thonet’s M-209 bentwood armchair (circa 1900), exemplifying curvilinear elements that designers could describe as “noodle-y” or “playful.” This piece serves as a reference point in fCrit’s dialogue demonstrations, illustrating how the system connects intuitive observations to structured formal concepts.

<https://www.thonet.de/en/all-products/detail/209>.

feedback modality (Oh and Oh, 2017), cognitive ergonomics (Tianfield and Wang, 2004), and contextual awareness (Fischer, 2012).

Recent studies have explored integrating tutoring system capabilities enhanced by large language models (LLMs) (Ashfaque et al., 2020; Ait Baha et al., 2024). However, these remain ill-equipped for the deeper forms of learning required in design education. This gap underscores the opportunity for a system tailored to design learning, with a focus on *adaptive design thinking* (Sharp and Macklin, 2019), *deep reflection* (Redström, 2017), and *problem framing* (Cross, 2006; Getzels and Csikszentmihalyi, 1976).

With these considerations, we employ Gebrüder Thonet’s M-209 armchair (Fig. 1) as the reference piece to elucidate key points in the following sections.

Theoretical Framework

To support adaptive design thinking, reflective learning, and problem framing, we developed a theoretical framework that integrates three complementary models to shape the user experience in fCrit:

Reflective Learning: This component draws on Schön (1992b) theory of reflection-in-action and Moon (2013) model of structured reflection. Rather than prescribing solutions, fCrit is designed to amplify the designer’s own observational process. It scaffolds both spontaneous and deliberate reflection, positioning critique as a site of sensemaking rather than evaluation. This aligns with work in creative cognition that emphasizes iterative reasoning and metacognitive engagement in design practice.

Mixed-Initiative Interaction: The system adopts a mixed-initiative paradigm (Allen, Guinn, and Horvitz, 1999)

to facilitate a dialogic relationship between humans and AI. Rather than issuing corrections, fCrit engages users in multi-turn, context-sensitive conversations. This model has seen success in creative domains such as game design (Bueno Perez and Bidarra, 2022) and generative furniture design (Buonamici et al., 2020), offering an interaction structure well suited to exploratory and co-creative tasks.

Formal Critique Vocabulary: To enable design discussions based on real-world practice, fCrit employs a vocabulary derived from formal critique traditions (Dondis, 1974; Wong, 1993; Hannah, 2002). The knowledge base encodes relationships among elements such as line, shape, form, and space, making them accessible at multiple levels of abstraction and formal awareness. This structured lexicon allows the system to link user observations to established design principles, fostering visual literacy without constraining creative freedom. An important feature of formal critique is that it does not concern itself with regional-stylistic or period-based labelling (e.g., Scandinavian or Victorian). Instead, it focuses solely on the perceptual effect of pure form.

Together, these three model components address the gaps in past critiquing systems, positioning fCrit not as a rule-based assessor, but as a reflective partner in design critique. The system supports the emergence of creative insight through dialogue, aiming to foster a sense of mutual attentiveness between designer and AI. This human-centred approach enables the system to contribute without imposing, sustaining the designer’s creative agency while enriching the discursive depth of critique.

fCrit: Furniture Design Critic

Inspired by the progressive depths of reflection discussed in Hatton and Smith (1995) and Moon (2013)—who categorized reflection into descriptive, reflective, dialogic, and critical levels—we designed fCrit to support reflection and theory application at varying depths, tailored to users’ needs. The system operates across multiple levels of reflexivity: at the foundational level, it mirrors the user’s observations to invite further reflection. As dialogue deepens, it introduces design terminology, identifies patterns and relationships between elements, and ultimately contextualizes observations within broader design implications. This progressive capability aims to support users without overwhelming them with excessive theoretical complexity. To enable this functionality, the chatbot incorporates augmentative tools to: (1) analyze and detect user intent to determine and define a communication path; (2) match the user’s language and formal awareness level; and (3) access a knowledge base of furniture-specific visual concepts and patterns.

Critique Knowledge Base

fCrit’s knowledge base is built specifically for formal critiquing and is constructed in such a way that captures each visual *concept* and *pattern* in a single structured embedding. Each embedding contains all the necessary contexts for the LLM to understand the nuance and relations with

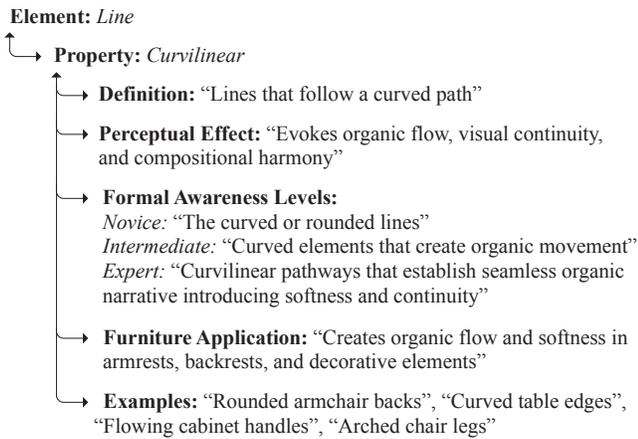


Figure 2: Hierarchical representation of Curvilinear Line in fCrit’s knowledge base, showing how visual concepts are structured with formal definitions, perceptual effects, awareness-tailored language, applications, and examples to support adaptive design critique.

other concepts. The concepts and patterns are derived from umbrella parents such as *Line* into more nuanced concepts (e.g., curvilinear line, diagonal line, etc.). As shown in Fig. 2, within each of these conceptual embeddings are formal definition, perceptual effects, awareness-tailored language, domain-specific applications, and concrete examples. This structured approach enables the system to tailor explanations according to the user’s formal awareness level while maintaining consistent underlying design principles.

The knowledge base is implemented using Supabase Vector Store,¹ an open-source Firebase alternative that provides a dedicated PostgreSQL database with vector search capabilities. This setup allows the LLM to access and reason over the knowledge base in an intuitive, multi-layered way. For example, if a designer describes Thonet’s M-209 chair in Fig. 1 as “noodle-y” and “playful”, the system guesses that they may be talking about the dynamic curvilinear elements of the chair. This allows the system to surface and expand on the underlying visual insight. In the Dialogue Demonstration section, we illustrate how these interaction levels work in practice, demonstrating fCrit’s ability to both adapt to a designer’s evolving observations and stimulate deeper engagement with visual forms.

System Architecture

fCrit is implemented using n8n,² a workflow automation platform that enables visual workflows for connecting various API endpoints as modular “nodes.” Within n8n, fCrit orchestrates an agentic workflow comprising five specialized components: the Command Hub, Design Concept Mapper, Pattern Recognition Engine, Etiquette Classifier, and Dialogue Agent. As shown in Fig. 3, the system operates across three tiers—input processing, knowledge access and adaptation, and dialogue generation—each supported by task-appropriate language models. To maintain focus and interpretability, fCrit retrieves knowledge from its structured

base on a just-in-time basis, introducing information only when relevant to the ongoing interaction. Each retrieval is accompanied by a confidence score, enabling system-level introspection and iterative refinement of concept mappings. The architecture is optimized for co-creative engagement through distributed reasoning and modular control. For language processing, we use different Anthropic’s Claude models, depending on each agent’s need for speed, interpretive nuance, and cost-efficiency. System prompts are carefully structured to ensure consistency across interactions.

Command Hub. This is the central entry point for all user input and orchestrates the flow of information across the system. It serves as the coordination layer that routes each user message through a selection protocol to determine relevant design concepts, visual patterns, and shifts in user intention.

Upon receiving input, the Command Hub outputs a set of boolean flags in JSON format that indicate whether any of these dimensions are present. These flags define a focused processing context for the subsequent components, ensuring each downstream module operates only when needed.

Designed for robust reasoning and fast turnaround, this component leverages Claude 3.5 Haiku to balance speed with nuanced understanding. Its tiered activation strategy enables the system to dynamically adjust computational resources, invoking only necessary tools per interaction. In doing so, the Command Hub ensures efficient, context-aware orchestration across the multi-agent architecture.

Pattern Recognition Engine. This component detects visual patterns. It works with the user observation and the knowledge base to suggest implied visual patterns (i.e., unity, contrast, repetition, alignment, and progression; each with sub-patterns such as rhythmic repetition, size progression, etc.). It detects mentions of visual pattern or relationship in user input and determines the pattern implications or suggestions. As one of the two components that has access

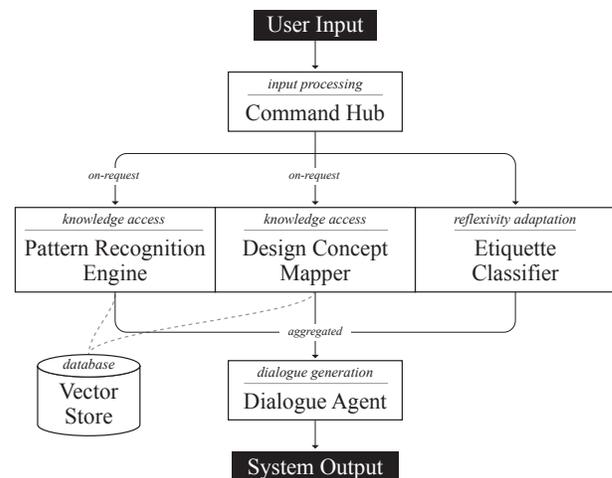


Figure 3: fCrit architecture: Five specialized AI agents work in a three-tiered workflow to process user input, access design knowledge, and generate furniture critiquing dialogues with adaptive levels of reflexivity. Two of them gain on-request access to a domain-specific knowledge base.

¹ <https://github.com/supabase/supabase>

² <https://github.com/n8n-io/n8n>

to the design knowledge base, it assigns a confidence score to every extraction (i.e., if the score is low, we can identify potential missing concepts in the knowledge base).

Design Concept Mapper. This agent translates natural language observations into formal design critique terminology. It identifies design elements in the user input and extracts visual concepts (i.e., line, space, form, shape; each with sub-concepts such as diagonal line, negative space, etc.) from the knowledge base. Similarly to the Pattern Recognition Engine, it also assigns a confidence score to each extraction from the knowledge base. In terms of enhancing relevance and focus, it tailors its outputs according to user language and formal awareness levels and acts as a conceptual guardrail to prevent unnecessary expansions to other concepts. Both components in this parallel sub-workflow perform simple natural language processing tasks, so we use Claude 3.5 Haiku to ensure cost-effective, rapid parsing of conceptual cues.

Etiquette Classifier. This is a conversation classifier that analyzes user messages to determine appropriate language mode. There are three modes: casual, detailed, and deep. This capability is essential to reflective learning and Mixed-Initiative Interaction as it fosters positive emotional states as it reinforces a shared language space. This component analyzes user input to determine the critique’s language mode, recommends response length and formality based on input complexity, optimizes the timing of probing questions, and packages this information for aggregation down the pipeline.

Dialogue Agent. This module synthesizes outputs from all prior components to produce content-aware replies. It progressively scaffolds *Reflective Learning* by activating different depths of reflectivity through adaptive, critique-focused dialogue.

When engaging with users, the agent connects their observations to design theory using *Formal Critique Vocabulary*. For example, if a designer describes a chair like the one in Fig. 1 as “noodle-y, playful, and elegant”, the Dialogue Agent works to discover and expand the connections between these observations and relevant formal theory.

The component utilizes three tools to accomplish this task. First, it rephrases user input using design-related language to nudge further elaboration from the designer (e.g., “I can see why...”). Second, it poses generative questions to focus the designer’s attention on the *why* behind their observations, promoting convergent thinking (e.g., “What makes you think...?” or “Do you notice...”). Third, it creates visual analogies bridging to everyday concepts to probe divergent thinking (e.g., “The flowing lines resemble...”).

Before delivering the final response, the agent implements a quality self-validation process, checking for: user-centeredness (reflecting observations, following user focus), appropriate design knowledge integration (terminology matching user formal awareness level), and conversation naturalness (appropriate length, flow, and questioning). To handle these linguistically demanding tasks, the system employs Claude 3.7 Sonnet, which offers a larger context window and improved discourse handling.

This enables the system to track ongoing conversational themes, maintain continuity, and facilitate evolving levels of formal critique.

The integration of our formal critiquing-specific knowledge base with our retrieval-based architecture delivers the key user experience benefits outlined earlier. By focusing on a single scope of exploration at a time, this gradual approach to explainability enhances the designer’s reflective experience rather than overwhelming them with too many perspectives. Furthermore, it establishes a shared mental space for human-AI mixed-initiative creative exchanges where the AI gains additional context about the ongoing observation through every dialogue turn, further building collaboration and trust through human-centered dialogue techniques. Throughout the process, fCrit preserves the designer’s creative agency by following their lead and introducing relevant design insights only when appropriate.

Dialogue Demonstration

The following dialogue presents one interaction with fCrit over four turns, using Fig. 1 as the reference piece for critique. These inputs were carefully selected to trigger its critiquing capabilities to effectively support reflective learning.

Designer: Hi, I like this design (*with Fig. 1 attached*).

fCrit: What specifically attracts you to this chair design? I notice it has those beautifully bent wood elements that create a continuous flowing line from the backrest to the armrests. The natural light wood tone gives it a timeless quality too.

Designer: Well I’m drawn to how noodle-y it looks. It’s playful yet elegant!

fCrit: I love your description of it as “noodle-y”! That’s a great way to capture those continuous curved lines. The way the wood bends and flows without interruption creates that playful character you’ve noticed, while still maintaining an elegant presence. Do you think it’s the smoothness of the curves or the rhythmic repetition of the lines that gives it that playful quality?

Designer: I think it’s in the way the curved lines traverse across different parts of the chair, tying it together to create a story. What do you think about this linear narrative?

fCrit: That’s very perceptive! Those curved lines do more than just connect physical elements—they create a visual journey through the chair’s form. The way each curve flows into the next creates a sense of continuity that tells a story of movement and rhythm. It’s almost as if the designer wanted us to experience the chair as a single gesture rather than separate parts. The curves also guide the eye around the entire piece, revealing how intentionally unified the design is. Do you feel this narrative quality makes the chair more inviting or more sculptural in nature?

Designer: This narrative definitely invites closer inspection. There’s something else about the nature of curve that feels amiable. I can’t quite find the right word.

fCrit: There’s a certain warmth and hospitality in organic curves that straight lines often lack. Perhaps what you’re sensing might be described as “haptic invitation”—the way these gentle curves seem to welcome touch and interaction. The curves have a natural ergonomic quality that resonates with our bodies and movement patterns, creating an immediate sense of comfort even before physical contact.

The gradual, predictable nature of these curves also creates visual ease—our eyes can follow them without abrupt interruptions, which might contribute to that feeling of amiability you’re describing. Does that resonance with human movement patterns and visual comfort capture some of what you’re feeling about these curves?

fCrit employs a multitude of dialogue techniques and critiquing initiatives not only to develop reflexivity, but also to build trust, foster positive emotion, and expand perspectives—which serve as auxiliary components to ease reflective learning (Moon, 2013).

The first turn demonstrates fCrit’s *question-first protocol* when the designer’s interests are unclear or for new topics, prioritising understanding what the designer likes before offering analysis. This intentionality is reinforced by *response-length control* which prevents the system from dominating initial dialogues while still advancing the critique. The second turn presents the system’s capability to use *designer-centered language* to elaborate on the designer’s previously expressed interest rather than imposing new directions. The final two turns showcase fCrit’s *grounded interpretation* which validates and builds upon the designer’s characterizations and metaphors and the use of *open and gauging questions* to encourage the designer’s own reflections or feedbacks on whether the system response is relevant or helpful.

In essence, fCrit utilizes formal critique as a vehicle for reflective learning, prioritising the subtle unpacking of observations into reflective insights over the prescriptive components of critique such as regional-stylistic or period-based labelling. fCrit more closely aligns with design practitioners’ need to interpret and internalize how pure forms work by scaffolding for design vocabulary and concepts that might help the designer articulate their own thoughts.

Conclusion & Future Work

The planning for further development of fCrit focuses on two key areas. First, we conduct a user experiment with both novice and expert furniture designers to gauge the system’s helpfulness on design reflective practice. Then, we analyze the results of this experiment to refine and improve fCrit’s critiquing capabilities.

The gap between existing AI solutions and creative needs presents a unique opportunity for design learning systems. To echo Verganti, Vendraminelli, and Iansiti (2020), current innovation in problem-finding is severely limited as AI solutions orient towards problem-solving instead. fCrit tackles this issue with a specialized AI agent that helps develop visual thinking in designers, aiming to deepen design sense-making through reflective learning.

Our system design employs various prompting and component routing techniques to augment the system’s capacity to maintain human-centredness, critique-focus, and relevance. This approach is supported by a methodology for constructing a knowledge base that organizes furniture design concepts with layers of depth and interpretations. The result is a multi-layered dialogue system capable of reflective design critique that mirrors critical aspects of traditional critiquing without attempting to replicate it.

Our research on fCrit has opened new avenues and sparked conversations for future chatbot and explainable systems beyond furniture design critique. As design thinking continues to evolve alongside technological capabilities, problem-finding oriented systems like fCrit could transform how designers engage with both their creative process and the theoretical foundations that inform their practice.

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