ProConte: Supporting Progressive Authoring of Anime Storyboards through Partial and Exceptional Representations

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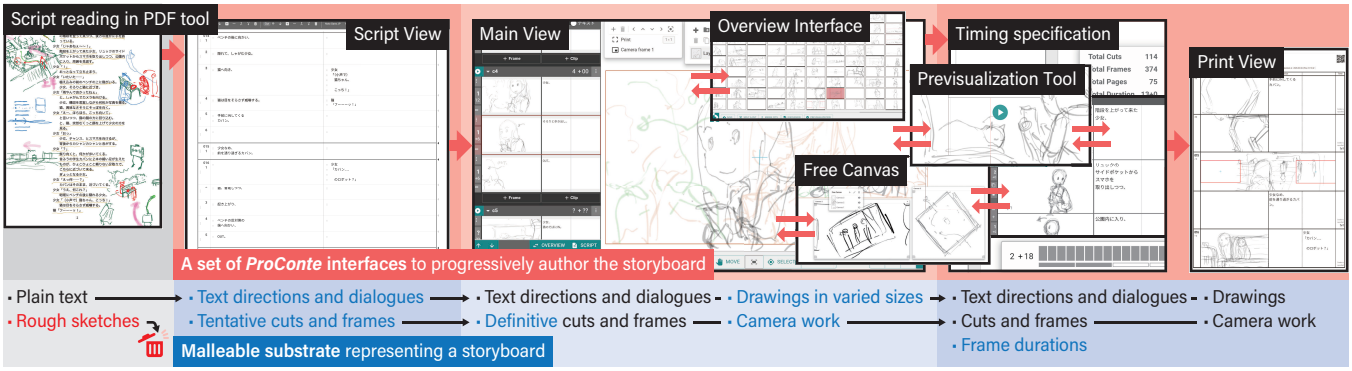


Figure 1: Anime storyboarding proceeds mostly irreversibly, with some information added, some carried forward and refined, and some selectively discarded. A malleable substrate allowing various intermediate representations supports this process.

Abstract

Creative practice is rarely fully formal. Even in highly structured production settings, professionals routinely rely on incomplete entries, deferred decisions, and exceptions to standard formats in order to think, explore, and communicate. In storyboard authoring, such deviations are not edge cases but part of the work itself. We present ProConte, a user interface for Japanese animation (anime) storyboarding that accommodates partialness and exceptions through a malleable substrate and a set of coordinated interfaces. Developed in close collaboration with a professional anime director, ProConte supports unspecified timings, exceptionally sized frames for expressive camera work, and unordered free-canvas frames for tentative externalization. The director used ProConte to author the complete storyboard for a 25-minute television anime episode, and we conducted six two-hour lecture sessions in which he created storyboards while explaining his process aloud. Together, the episode production and lecture sessions provided complementary qualitative evidence: the former situated ProConte in real-world production, while the latter made the director's authoring process more inspectable. These materials showed that, in this case, our design supported progressive authoring in practice: ideas could be externalized before they were fully specified, revisited later, and developed across multiple semantically distinct stages without premature commitment to a formal structure.

CCS Concepts

• **Human-centered computing** → **Human computer interaction (HCI)**; *User interface design*; *Graphical user interfaces*; • **Computing methodologies** → **Animation**; • **Applied computing** → *Media arts.*

Keywords

Creativity support, animation, storyboard, user interface, interaction substrates

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1 Introduction

Creative work is rarely completely formal. Even in domains with established production formats, creators often rely on incomplete entries, deferred decisions, and exceptions to standard structures in order to think, explore, and communicate. Such departures are not merely irregularities around an otherwise orderly workflow. In many cases, they are part of how creative work actually proceeds.

Japanese animation (anime) storyboarding provides a compelling use case. In anime production, the storyboard, commonly called E-conte, is a key pre-production artifact that translates a scenario script into a specification for images, stage directions, dialogues, timings, and camera work. Storyboard authoring, however, is not merely a matter of completing that specification. It involves selectively fixing some elements, deferring others, and occasionally departing from the default format. Supporting such partialness and exceptions requires more than a rigid form-filling interface. Instead, creators need a shared, malleable "substrate", or underlying representation, that preserves intermediate and irregular states without forcing premature normalization. Creators should be able to collaborate via a coordinated set of interfaces that offer different views and interaction styles.

Our prior work introduced Griffith[1], an integrated E-conte authoring environment developed with anime professionals [8]. ProConte builds on Griffith to examine how coordinated interfaces over a shared substrate can preserve partial and exceptional states as authoring progresses. More broadly, research in creativity support tools shows the benefits of letting users cross levels of abstraction [12], warns against premature commitment [3], and highlights the role of external representations in reinterpretation and idea development [21, 24]. Li et al. [11] argue that departures from intended or normative use should not be treated simply as "incorrect behavior", but rather as reactions to the broader context of traditional practices, industry norms, and the tools themselves. This raises an important challenge: How can tool designers balance the creators' desire to explore alternative representations with their need to converge on a highly formalized production artifact? We address this question through the design and study of ProConte, a storyboarding tool that accommodates partialness and exceptions through a malleable substrate and a set of coordinated interfaces: the substrate preserves a shared representation even when timings are unspecified, frames are oversized, or ideas are tentatively externalized, while the interfaces support work on that evolving material across multiple linked modes of authoring.

We separate the paper's evidence and contributions at three levels. First, we report director-specific observations from an in-depth participatory case, including the director's ordering and appropriation of ProConte. The case-specific evidence does not establish usability across storyboard artists. Second, we characterize domain-grounded requirements of time-coded storytelling media and present a malleable substrate with coordinated interfaces that supports intermediate representations while converging on a formal E-conte artifact (Figure 1). These requirements include linked script and storyboard structures, cuts, frames, camera directions, dialogue, timing, and print-oriented downstream use. Third, we offer broader design lessons about which layers to commit first, which to leave partial, and how to preserve useful exceptions during progressive authoring. We frame these lessons as analytically transferable questions rather than universal interface prescriptions.

2 Related Work

Creative practice often involves transitioning through multiple representations rather than authoring within a single, stable view. Li et al. argue that creativity support tools should support movement across levels of abstraction and across tools, thereby shaping a different normative ground [12]. Storyboard authoring fits this framing, but our focus is not only on movement between representations. Instead, we ask how creators can work on the same evolving artifact from multiple angles without resolving it too early into a fully formal state. Prior work on anime storyboarding [8] focused on understanding practice and bringing benefits of the paper-based E-conte format into digital tools. This highlights the need for tools that support progressive development and exception handling, where different creators can collaborate on partially specified storyboards throughout the production process.

Interaction Substrates describe how multiple interfaces can operate over shared material by defining the structure, constraints, and dependencies of the material [14]. This view is compatible with recent interest in malleable interfaces, where the goal is not a single fixed interface form but one that can accommodate changing needs and perspectives [16]. We are interested in applying this approach to a domain in which the target artifact must remain open, with uneven progress that may break the predefined format at different points in the production process.

Systems such as QuickCut [23] and CARDINAL [15] also connect distinct representations, but focus primarily on navigating or interpreting linked representations rather than on authoring a shared substrate. Other systems show that supporting expert work on structured artifacts may also require temporarily relaxing the structure itself: EuterPen selectively relaxes syntactic and structural constraints in music notation editing [2], while Spreadsheets on Interactive Surfaces enables direct manipulation on and through the spreadsheet grid with pen input [1]. The challenge is how to offer creators the ability to loosen these formal structures while authoring a production-level artifact.

Existing practices and tools range from paper and digital systems intended for E-conte authoring to systems developed for adjacent domains. Paper offers immediate drawing and flexible margins, but not linked identifiers, synchronized playback, or structured revision carry-over. Griffith already compared E-conte authoring with TVPaint, Storyboard Pro, and e-Conte Board, documented Procreate being repurposed for storyboarding, and used presentation software such as PowerPoint as a familiar example of visually sequencing a story along a vertical timeline [8]. More distant examples support other parts of audiovisual production: Scrivener targets writers and scripts, StudioBinder targets film and television production planning, and FrameForge constructs previsualizations and storyboards from 3D sets, actors, and cameras rather than hand-drawn frames.[2] Taken together, these comparisons show that E-conte authoring crosses domains rather than fitting a single tool

[1] Griffith project website: https://research.archinc.jp/en/griffith/.

[2] Official product information: Scrivener; StudioBinder; FrameForge.

category. It therefore offers a compelling setting for studying real-world creative work in which interdependent elements of writing, drawing, camera framing, timing, layout, and previsualization are progressively specified in a consequential order.

Early research on creativity support tools argues that interfaces should support experimentation, exploration of variations, and continuous progress evaluation [22]. More recent research with creative professionals suggests that such interaction strategies should presume substantial expertise [6]. Work on creative misuse similarly frames departures from intended use in relation to broader normative ground rather than as mere error [11]. The problem is how to design tools that do not force experts to consistently comply with the formal E-conte logic until they reach the end of the creative process.

Recent AI-supported storyboarding systems such as CineVision [26] and StoryEnsemble [20] expand opportunities to move among representations by linking stages, maintaining consistency, and accelerating iteration. These capabilities make it important to ask not only how creators can move between stages or fill gaps faster, but how such flexibility relates to convergence on a formal artifact. This question also matters because generative AI can increase design fixation and reduce divergent thinking during ideation [25].

Shipman and Marshall's incremental formalization describes how an underlying representation can become progressively explicit without requiring complete structure upfront [19]. It concerns the representation itself becoming more formal, not merely iterative gains in fidelity. At a complementary level, Fischer et al. show how users extend a seeded environment during use and later reorganize and formalize its accumulated knowledge through reseeding [4]. This tool-level flexibility raises a related question: how can an authoring environment help creators decide which holes in a shared substrate to fill, which parts to commit, and when? Design-rationale research and reflective practice further explain how reasoning develops and becomes inspectable through action [17, 18]. The remaining design question is how coordinated interfaces can support this order of commitment while preserving deliberate incompleteness, domain-specific exceptions, and selective carry-over toward a formal production state.

3 ProConte: Progressive Anime Authoring

We developed ProConte in close collaboration with a professional anime director. Although the final E-conte storyboard follows the industry-standard format and appears to be a highly formalized production artifact, we discovered that the actual authoring practice is much less formal than the finished format suggests. Rather than directly filling in a fixed template, the director moved across multiple representations, selectively carrying some materials forward while intentionally leaving others behind. We therefore developed ProConte not as a single form-filling editor, but rather as a malleable storyboard substrate with coordinated interfaces that support stage transitions, preserve openness where needed, and accommodate exceptions that remain important in professional practice.

The shared substrate keeps script structure, drawings, camera directions, timing, and auxiliary materials available without requiring simultaneous finalization. The director begins the complete authoring loop by importing and segmenting the script (Figure 1). He then elaborates linked cuts and frames through local editing and sequence overview, uses separate camera and print frames for camera work and exceptional layouts, and keeps unordered visual material in a free canvas. He finally specifies timing while previewing the evolving board, including frames whose timing remains unspecified. The following subsections present the interfaces in this case-specific order and identify the production problem to which each responds. Within each subsection, we distinguish the director's ordering and appropriation from requirements of the E-conte artifact; broader implications are developed in the Discussion.

The present case begins with a scenario script, although some anime productions adapt manga. The director explained that manga panels can serve as visual references and may sometimes be deliberately echoed for readers, yet they are not ready-made E-conte frames. In his account, adaptation teams select, omit, compress, reorder, or add material under runtime constraints, then stage retained panels and added scenes as time-based shots. A useful extension to ProConte would link script context to corresponding source panels.

3.1 From Script Reading to Script View

The first design issue appeared at the transition from script reading to storyboard authoring. Before using ProConte, the director read the scenario script in an external PDF annotation tool, imagining scenes and making rough sketches while following the text. He did not use these sketches in later stages because he wanted to maintain a fresh perspective and see the material from the viewer's perspective.

This suggests that some experts may not want to preserve all intermediate traces. What mattered here was not the complete transfer of prior materials, but the ability to move to the next stage while keeping the process malleable. A lightweight way of optionally bringing such sketches back, for example by pasting them into the later free canvas (Section 3.5), remains a promising direction for future work.

What ProConte *does* carry across this transition is the entire script in plain text. This copy-and-paste step may appear trivial, but in practice, it plays an important role. His previous workflow involved copying and pasting the script excerpts one by one, while the director added drawings, considering text and visual representations at the same time. ProConte instead uses a text-based representation that lets the director postpone visual commitment and work on segmentation before drawing.

3.2 Script View: Structuring Before Drawing

ProConte thus includes a *script view* for structuring the as-yet-unvisualized storyboard. It lets users insert and revise cut and frame boundaries while focusing on textual flow. This resembles QuickCut [23], a text editor linked to speech transcription that coordinates lightweight editing with another representational layer.

However, unlike prior work focusing on editing completed representations, our approach to text editing does not assume an already completed counterpart. The director preferred to progressively build up the artifact by first stabilizing its plain-text organization and only later adding drawings and camera work. This design decision reflects a broader principle that recurs throughout the system. When a creative artifact is still full of "holes," it can be beneficial

to let the user focus on one representational layer at a time, rather than forcing the early integration of all layers. Rather than disappearing as preprocessing, the segmented text remains a revisable scaffold as other layers are added.

Even at this stage, however, "plain text" was not truly plain. The director sometimes needed to indicate vocal qualities such as shouting, as well as exceptional textual elements such as onomatopoeia, through changes in font size, style, and color. For this reason, *script view* supports rich text rather than raw text. This is a small but important example of the argument of this paper: even when a workflow appears text-based and regular, professional practice may still require local departures from a uniform representation.

3.3 Editing and Overview: Elaborating Sequence

After segmentation, authoring proceeds through repeated movement between local elaboration and global inspection, a pattern described as "view-shifts" [5] and already reported in prior work [8]. ProConte supports this stage with a *main view* for concentrated work on individual cuts and frames and an *overview interface* for inspecting the sequence as a whole, reconsidering the broader flow of the episode, and revising the unit structure itself by splitting cuts or merging them when a different granularity becomes necessary. Unlike in prior work, the already segmented text was carried over from the *script view*. The director elaborated it in the editing interface by attaching drawings to existing lines and further extending them with camera directions.

Throughout authoring with the editing and overview interfaces, details are added progressively. Text usually comes first, functioning as a scaffold for later additions. Drawings are attached to this textual structure, and camera work is added on top of the drawings. Only at this point does a more quantitative sense of duration begin to emerge, though the work is still not reduced to explicit timing values. The focus remains on the felt quality of motion and sequence rather than on assigning final durations. Local and global shifts thus layer decisions onto an incomplete structure rather than filling a fixed form at once.

3.4 Editing for Print: Formal Layout with Built-In Exceptions

Camera work shows the limits of the default printed format. A horizontal pan, for example, cannot be represented simply by drawing a sequence of frames of fixed size. Instead, it is often better represented as a larger underlying sketch with an overlaid camera frame. This led us to design the editing interaction around the relation between a drawable image area and a separate camera frame.

From a pragmatic perspective, the printed storyboard format still matters, because the storyboard ultimately serves as a document for directing animators and other experts in the production process. The sequence of frames stacked vertically in the editing interfaces therefore remains close to the printed format, except that it does not include pagination for printing. This requirement exposed a deeper design issue. In printed E-conte, image areas and text areas are organized in a highly regular page structure, yet professional practice repeatedly demands exceptions to that structure.

To accommodate such cases, ProConte supports image regions that can expand horizontally and vertically beyond the default unit frame while remaining compatible with the printed layout. As shown in Figure 2, this is handled through the same layout logic as the printed format, together with the notion of a *print frame* in addition to a camera frame.

From a design perspective, the interface could not treat the printed storyboard simply as a static template to be filled in. It had to support exceptional uses of space within the printed layout, something closer to a grid whose cells can sometimes be merged, stretched, or partially violated.

3.5 Free Canvas: Out-of-context or Global Notes

Another challenge in the director's workflow concerned notes, reminders, and reference materials. He wanted to jot down ideas that did not fit neatly into the storyboard fields and to keep global references such as character settings information nearby. On paper, he handled such information by breaking the printed form itself, for example by sketching over regions reserved for text, or by spatially arranging reference materials around the paper on the desk. In this workflow, these were practical ways of managing context that the formal artifact alone could not contain.

Guided by the director's tacit knowledge, we reinterpreted rather than replicated these paper exceptions according to representational strengths: searchable textual deviations remain rich text, while a *free canvas* holds open-ended visual notes and references.

The free canvas is implemented as drawings attached to cuts that do not belong to the ordered storyboard sequence. It functions like a pinboard or floating notebook that can remain available across stages. Individual drawings can be shown or hidden at any time. The director used out-of-frame notes for context-specific remarks that belonged near a particular cut (described as "margins" [5]), while using the free canvas for less context-dependent notes and references that should remain available more globally.

3.6 Timing Specification: Closing the Last Hole

Even after the text, drawing, and camera work have been progressively elaborated, explicit timing is still missing. The director filled this hole so that the embodied sense of pacing would fit the fixed runtime of approximately 25 minutes for a television episode. ProConte supports this process with a *stopwatch tool*, *timing statistics*, and *timing hints* shown next to the frames.

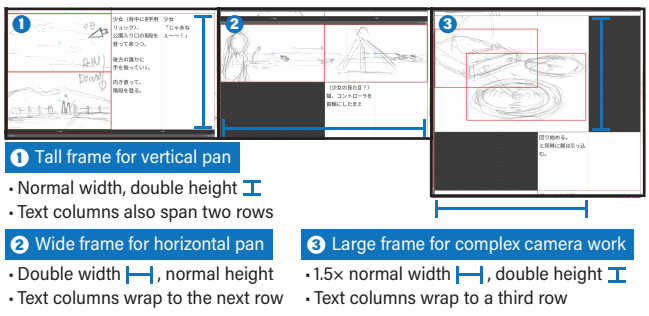


Figure 2: Examples of exceptional storyboard layout in ProConte where image regions expand to push text areas.

For this director, the ordering mattered. Rather than treating timing as a parameter to be assigned from the beginning, the process lets the temporal structure emerge gradually from prior textual decisions (the order of events, with implicit timing sometimes estimated from the length of the dialogue), visual decisions (who appears in each scene and in what kind of composition, with implicit timing sometimes estimated from visual complexity), and camera-related decisions (what kinds of actions are performed, which also carry implicit timing information). Here again, the apparently formal final artifact concealed a process in which different kinds of decisions became fixed at different times.

The previsualization tool that plays the storyboard as a video is available across stages, and it plays frames without timing information using a default duration. This lets the director preview rough timing before using the timing view and revisit explicit frame timings. Together, these interfaces make formalization gradual by staging commitments while preserving selective carry-over, layout exceptions, and material outside the main sequence.

4 Discussion

We combine the completed episode, six think-aloud lecture sessions, and interaction traces as complementary within-case evidence and creative activity traces [10]: the episode establishes production deployment, while the lectures make the director's choices more inspectable. The episode board contains 1,036 final frames—38 exceptional (3.7%)—plus 320 non-final frames retaining timed drawing objects; the lecture board contains 416 final frames, including seven exceptional frames (1.7%). Together with two representative trajectories, these traces show recurring exceptional and non-final states, revisitation, and backward movement. Appendix A reports methods and caveats; these measures are process indicators, not prevalence estimates.

4.1 Progressive Authoring Beyond Iteration

Interaction Substrates provide a useful account of how multiple interfaces can operate over shared material through structure, constraints, and dependencies [14], but do not address how authoring unfolds over time when different parts of an artifact should become fixed at different moments. Our case suggests that the issue is not only how views stay coordinated, but also how interfaces support *staged commitment*. We use *progressive authoring* to describe this process: the work does not proceed by repeatedly refining one stable representation, but by moving across semantically distinct stages in which some decisions are stabilized, others remain open, and some traces are selectively not carried forward. In *script view*, segmentation becomes stable before drawing; in the editing and overview interfaces, text remains as a scaffold while images and camera directions are layered onto it; timing is often closed last, yet rough preview remains possible beforehand.

This matters because professional production should not be idealized as unconstrained creativity. In commercial animation, time is money, and more elaboration does not necessarily produce a better result. Professional creators routinely work through compromises, so a useful interface must support neither rigid early formalization nor endless exploration, but practical movement between temporarily useful states.

Our interviews suggest that this issue extends beyond storyboarding. A screenwriter described beginning with relatively stable later acts and working backward, while a comic artist treated plot construction as a distinct stage and warned that an exciting scene can become a "branch" without a strong "trunk." These accounts motivate the order of commitment as a question for neighboring creative domains; Section A.4 provides context. Future tools might support low-commitment work on premises and large-scale structure while retaining scene ideas for later retrieval.

4.2 Malleable Substrates for Formal Artifacts

When digitizing an analog production practice, it is tempting to begin from the final format and reproduce its visible structure. Prior work on anime storyboarding showed that this is insufficient: what mattered was not only replacing pen and paper, but also accounting for the broader working environment, including auxiliary tools such as a stopwatch [8]. Our use case suggests that even this is not enough. If designers attend only to the apparent formality of the finished artifact, they risk missing how analog practice actually uses partialness, exceptions, and format-breaking material during creation. What may generalize is not a prematurely unified substrate, but a more precise account of the specific kinds of non-final and irregular states that expert work depends on.

This has direct implementation consequences. A malleable substrate cannot be realized simply by making everything equally editable. For professional work, it must preserve the formal structure required for downstream production while also representing non-final and irregular states. Which irregular states remain acceptable is stage-specific: in professional anime colorization, even a single unpainted pixel can require a costly retake, making such gaps defects to eliminate rather than provisional states to preserve [9]. In our case, these include unspecified timing, deferred visual detail, expanded frame regions, rich-text deviations, and unordered side materials. More generally, the design approach should not seek to remove constraints, but identify the specific aspects of expert practice that need computational support.

For interaction designers, this suggests three practical lessons. First, treat incompleteness as a valid working state rather than an error to resolve immediately. Sensible defaults can keep null states usable; for example, ProConte's previsualization tool plays untimed frames using a default duration. Second, data models should support reinterpretation, not only fixed functions. Reusing a data type can accommodate an adjacent practice; in ProConte, unindexed storyboard frames function as a free canvas. Third, systems can preserve visual formality while allowing structured spatial irregularity. Exceptional image regions can push neighboring regions while remaining precise integer multiples of the normal unit.

4.3 Limitations and Theoretical Implications

The single-director design bounds the claims to an analytically rich case rather than representative usability evidence. The director's long production and teaching experience provides unusually reflective access to expert practice, but other storyboard artists may order commitments differently or appropriate the interfaces in other ways. The lecture setting also makes reasoning inspectable

under conditions that differ from ordinary independent production. Future evaluation with a broader range of practitioners must determine which benefits remain robust across workflows.

We distinguish what this case supports at three levels. Case-specific observations include this director's ordering, alternatives, and uses of ProConte. Domain-grounded requirements concern the separate script and storyboard artifacts, cuts and frames, camera and dialogue information, timing, and print-oriented downstream use of time-coded storytelling media. These are requirements of the E-conte artifact and its downstream production use, rather than preferences specific to this director. The case shows how they shape interface design, but does not establish that all storyboard artists handle them in the same way. Broader design lessons concern an extension to interaction substrates: coordinated interfaces must manage not only shared material but also when its layers become committed, which exceptions remain usable, and which traces carry forward. Prior work shows that conventions can both structure and constrain creative work [11]; our case makes the temporal ordering of such commitments visible. We therefore offer partialness, exceptions, and staged commitment as questions for designers of formal creative-artifact tools, not as a universal interface pattern.

Such distinctions matter because claims of generality rest on often implicit assumptions about which people and practices count as representative, and which research problems enter the literature. Research on WEIRDness makes one such bias visible: CHI participant samples disproportionately represent Western societies [13]. Any claim of generality still requires justification, regardless of cultural setting. Research agendas introduce another filter: publication and evaluation norms in technically oriented computer science can privilege technological novelty, leaving culturally grounded knowledge such as anime production underexplored [7]. We hope this distinction offers one possible template for accumulating knowledge from culturally grounded HCI case studies: explicitly distinguish case-specific observations, domain-grounded requirements, and broader design lessons whose transfer remains to be examined.

5 Conclusion

Anime E-conte authoring must produce a formal visual and temporal specification while creative decisions remain partial and revisable. We presented ProConte, developed with an anime director and used to storyboard a 25-minute television episode. Production and lecture materials showed how coordinated interfaces over a malleable substrate supported progressive authoring in this case. These findings suggest a domain-grounded approach to authoring formal production artifacts without treating every hole or exception as an error requiring immediate resolution. We offer director-specific observations, domain-grounded requirements, and broader questions about staged commitment; studies with other storyboard artists should examine how these findings transfer across workflows.

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References

[1] Vincent Cavez, Caroline Appert, and Emmanuel Pietriga. 2024. Spreadsheets on Interactive Surfaces: Breaking through the Grid with the Pen. *ACM Trans. Comput.-Hum. Interact.* 31, 2, Article 16 (Jan. 2024), 33 pages. doi:10.1145/3630097

[2] Vincent Cavez, Catherine Letondal, Caroline Appert, and Emmanuel Pietriga. 2025. EuterPen: Unleashing Creative Expression in Music Score Writing. In *Proceedings of the 2025 CHI Conference on Human Factors in Computing Systems* (Yokohama, Japan) *(CHI '25)*. Association for Computing Machinery, New York, NY, USA, Article 760, 16 pages. doi:10.1145/3706598.3713488

[3] Nathan Crilly. 2015. Fixation and Creativity in Concept Development: The Attitudes and Practices of Expert Designers. *Design Studies* 38 (2015), 54–91. doi:10.1016/j.destud.2015.01.002

[4] Gerhard Fischer, Raymond McCall, Jonathan L. Ostwald, Brent Reeves, and Frank M. Shipman. 1994. Seeding, Evolutionary Growth and Reseeding: Supporting the Incremental Development of Design Environments. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems* (Boston, Massachusetts, USA) *(CHI '94)*. Association for Computing Machinery, New York, NY, USA, 292–298. doi:10.1145/191666.191770

[5] Jonas Frich, Michael Mose Biskjaer, Lindsay MacDonald Vermeulen, Christian Remy, and Peter Dalsgaard. 2019. Strategies in Creative Professionals' Use of Digital Tools Across Domains. In *Proceedings of the 2019 Conference on Creativity and Cognition* (San Diego, CA, USA) *(C&C '19)*. Association for Computing Machinery, New York, NY, USA, 210–221. doi:10.1145/3325480.3325494

[6] Baku Hashimoto and Jun Kato. 2025. Tweeq: Parameter-Tuning GUI Widgets by/for Creative Professionals. In *Proceedings of the 38th Annual ACM Symposium on User Interface Software and Technology* (Busan, Republic of Korea) *(UIST '25)*. Association for Computing Machinery, New York, NY, USA, Article 15, 16 pages. doi:10.1145/3746059.3747723

[7] Jun Kato. 2026. Fragmented Innovation: Anime and the Limits of Computer Science R&D. (March 2026), 3 pages. https://www.undonecs.org/2026/abstracts/UndoneCS26_abstract_57.pdf Non-archival abstract presented at the 2nd Conference on Undone Science in Computer Science.

[8] Jun Kato, Kenta Hara, and Nao Hirasawa. 2024. Griffith: A Storyboarding Tool Designed with Japanese Animation Professionals. In *Proceedings of the CHI Conference on Human Factors in Computing Systems* (Honolulu, HI, USA) *(CHI '24)*. ACM, New York, NY, USA, Article 233, 14 pages. doi:10.1145/3613904.3642121

[9] Masahiro Kono, Akinobu Maejima, Yuki Koyama, Yotam Sechayk, and Takeo Igarashi. 2026. No Pixel Left Behind: Filling Gaps in Anime Colorization. In *Proceedings of the 2026 CHI Conference on Human Factors in Computing Systems* (Barcelona, Spain) *(CHI '26)*. Association for Computing Machinery, New York, NY, USA, Article 300, 19 pages. doi:10.1145/3772318.3790968

[10] Max Kreminski, Amy Smith, John Joon Young Chung, Kihoon Son, Qian Yang, Sang Won Lee, Noor Hammad, Eric Rawn, Shm Garanganao Almeda, and J. D. Zamfirescu-Pereira. 2026. Herding CATs: Making Sense of Creative Activity Traces. In *Proceedings of the Extended Abstracts of the 2026 CHI Conference on Human Factors in Computing Systems (CHI EA '26)*. Association for Computing Machinery, New York, NY, USA, 1–5. doi:10.1145/3772363.3778743

[11] Isabel Li, Ace S. Chen, Eric Rawn, Shm Garanganao Almeda, Bjoern Hartmann, and Jingyi Li. 2025. Reimagining Misuse as Creative Practice: Impressions and Implications of Usage Norms on Digital Artists. In *Proceedings of the 2025 CHI Conference on Human Factors in Computing Systems* (Yokohama, Japan) *(CHI '25)*. Association for Computing Machinery, New York, NY, USA, Article 938, 14 pages. doi:10.1145/3706598.3714068

[12] Jingyi Li, Eric Rawn, Jacob Ritchie, Jasper Tran O'Leary, and Sean Follmer. 2023. Beyond the Artifact: Power as a Lens for Creativity Support Tools. In *Proceedings of the 36th Annual ACM Symposium on User Interface Software and Technology* (San Francisco, CA, USA) *(UIST '23)*. Association for Computing Machinery, New York, NY, USA, Article 47, 15 pages. doi:10.1145/3586183.3606831

[13] Sebastian Linxen, Christian Sturm, Florian Brühlmann, Vincent Cassau, Klaus Opwis, and Katharina Reinecke. 2021. How WEIRD is CHI?. In *Proceedings of the 2021 CHI Conference on Human Factors in Computing Systems* (Yokohama, Japan) *(CHI '21)*. Association for Computing Machinery, New York, NY, USA, Article 143, 14 pages. doi:10.1145/3411764.3445488

[14] Wendy E. Mackay and Michel Beaudouin-Lafon. 2025. Interaction Substrates: Combining Power and Simplicity in Interactive Systems. In *Proceedings of the 2025 CHI Conference on Human Factors in Computing Systems* (Yokohama, Japan) *(CHI '25)*. Association for Computing Machinery, New York, NY, USA, Article 687, 16 pages. doi:10.1145/3706598.3714006

[15] Marcel Marti, Jodok Vieli, Wojciech Witoń, Rushit Sanghrajka, Daniel Inversini, Diana Wotruba, Isabel Simo, Sasha Schriber, Mubbasir Kapadia, and Markus Gross. 2018. CARDINAL: Computer Assisted Authoring of Movie Scripts. In *23rd International Conference on Intelligent User Interfaces* (Tokyo, Japan) *(IUI '18)*. ACM, New York, NY, USA, 509–519. doi:10.1145/3172944.3172972

[16] Bryan Min, Allen Chen, Yining Cao, and Haijun Xia. 2025. Malleable Overview-Detail Interfaces. In *Proceedings of the 2025 CHI Conference on Human Factors in Computing Systems* (Yokohama, Japan) *(CHI '25)*. Association for Computing Machinery, New York, NY, USA, Article 688, 25 pages. doi:10.1145/3706598.

3714164
[17] Thomas P. Moran and John M. Carroll (Eds.). 1996. *Design Rationale: Concepts, Techniques, and Use.* Lawrence Erlbaum Associates, Mahwah, NJ, USA.
[18] Donald A. Schön. 1983. *The Reflective Practitioner: How Professionals Think in Action.* Basic Books, New York, NY, USA.
[19] Frank M. Shipman and Catherine C. Marshall. 1999. Formality Considered Harmful: Experiences, Emerging Themes, and Directions on the Use of Formal Representations in Interactive Systems. *Computer Supported Cooperative Work (CSCW)* 8, 4 (1999), 333–352. doi:10.1023/A:1008716330212
[20] Sangho Suh, Michael Lai, Kevin Pu, Steven P. Dow, and Tovi Grossman. 2025. StoryEnsemble: Enabling Dynamic Exploration & Iteration in the Design Process with AI and Forward-Backward Propagation. In *Proceedings of the 38th Annual ACM Symposium on User Interface Software and Technology* (Busan, Republic of Korea) *(UIST '25)*. Association for Computing Machinery, New York, NY, USA, Article 203, 36 pages. doi:10.1145/3746059.3747772
[21] Masaki Suwa and Barbara Tversky. 2002. External Representations Contribute to the Dynamic Construction of Ideas. In *Diagrammatic Representation and Inference*, Mary Hegarty, Bernd Meyer, and N. Hari Narayanan (Eds.). Lecture Notes in Computer Science, Vol. 2317. Springer, Berlin, Heidelberg, 341–343. doi:10.1007/3-540-46037-3_33
[22] Michael Terry and Elizabeth D. Mynatt. 2002. Recognizing creative needs in user interface design. In *Proceedings of the 4th Conference on Creativity & Cognition* (Loughborough, UK) *(C&C '02)*. Association for Computing Machinery, New York, NY, USA, 38–44. doi:10.1145/581710.581718
[23] Anh Truong, Floraine Berthouzoz, Wilmot Li, and Maneesh Agrawala. 2016. QuickCut: An Interactive Tool for Editing Narrated Video. In *Proceedings of the 29th Annual Symposium on User Interface Software and Technology* (Tokyo, Japan) *(UIST '16)*. Association for Computing Machinery, New York, NY, USA, 497–507. doi:10.1145/2984511.2984569
[24] Barbara Tversky. 2002. What Do Sketches Say About Thinking?. In *Proceedings of the AAAI Spring Symposium on Sketch Understanding (AAAI Technical Report SS-02-08)*, Tracy Stahovich, James Landay, and Randall Davis (Eds.). AAAI Press, 148–151. https://aaai.org/papers/0022-ss02-08-022-what-do-sketches-say-about-thinking/
[25] Samangi Wadinambiarachchi, Ryan M. Kelly, Saumya Pareek, Qiushi Zhou, and Eduardo Velloso. 2024. The Effects of Generative AI on Design Fixation and Divergent Thinking. In *Proceedings of the 2024 CHI Conference on Human Factors in Computing Systems* (Honolulu, HI, USA) *(CHI '24)*. Association for Computing Machinery, New York, NY, USA, Article 380, 18 pages. doi:10.1145/3613904.3642919
[26] Zheng Wei, Hongtao Wu, lvmin Zhang, Xian Xu, Yefeng Zheng, Pan Hui, Maneesh Agrawala, Huamin Qu, and Anyi Rao. 2025. CineVision: An Interactive Pre-visualization Storyboard System for Director–Cinematographer Collaboration. In *Proceedings of the 38th Annual ACM Symposium on User Interface Software and Technology* (Busan, Republic of Korea) *(UIST '25)*. Association for Computing Machinery, New York, NY, USA, Article 18, 18 pages. doi:10.1145/3746059.3747793

A Case Study Materials and Analysis

This appendix provides methodological detail for the case study summarized in Section 4. The materials ground the discussion of progressive authoring and malleable substrates for formal artifacts.

A.1 Collaboration and Episode Production

Building on Griffith [8], we developed ProConte through participatory collaboration with a professional anime director in Japan while he used the system in practice. The director reported continuous storyboard-authoring work since 1993, or approximately 33 years of professional experience at the time of submission (March 2026). His workflow and our observations of how he adopted and adapted the tool informed iterative design and implementation. He subsequently used ProConte to author the complete storyboard for a 25-minute television anime episode, providing evidence of real production deployment within this single case.

A.2 Lecture Sessions

To better understand the director's practice and how ProConte supported it, we asked him to conduct a series of online lectures on storyboard authoring for professionals in the anime industry who are interested in the storyboarding process[3] (Figure 3). He had substantial prior teaching experience: he reported giving internal direction lectures as early as around 2012, during the production period of *Gargantia on the Verdurous Planet*, and later teaching at multiple studios including Yokohama Animation Lab, MAPPA, and Kinema Citrus. He additionally reported teaching perspective lectures through JAniCA, a Japanese non-profit organization for anime creators, beginning in 2015.

The director created storyboards while explaining his process aloud during six lecture sessions of approximately two hours each. The completed episode documents real-world use, whereas the lectures make decisions, deferrals, revisions, and exceptional externalizations more inspectable in a teaching setting that differs from ordinary production.

We combined lecture transcripts and the resulting board with director-attributed interaction logs and persisted canvas-object timestamps. We restricted logged events to the storyboard owner/director on the six lecture dates, then associated them with frames using frame selections, local-to-canonical save mappings, and per-user active-frame state. We identified transcript passages where the director verbalized deferral, comparison, or commitment and checked their dates and sequence against logged frame selections, drawing activity, and current frame states. We report representative trajectories rather than coding frequencies for reasons or intentions. The completed-episode analysis excludes later inspection events and examines current storyboard structure and persisted object timestamps. These records reveal retained states but not historical deletion times or the intent behind every revision.

A.3 Trace-Informed Case Evidence

The completed episode contains 336 production cuts and 1,036 final frames, including 38 exceptionally sized frames (3.7%). The 830 frame records in non-final clips or the system's Trash include 320 frames that retain 64,243 timed drawable objects, or 17.5% of all timed objects. Those objects account for 8.43 hours of summed

[3] Storyboard lecture playlist: https://www.youtube.com/playlist?list=PL-5luj-qf3-CHSvmve7AW79J4MNS7-7Ne.

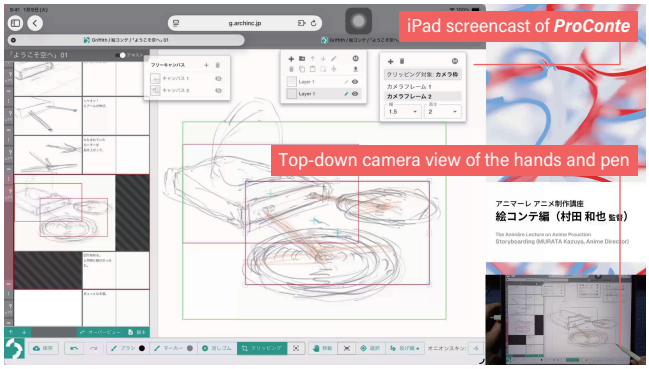


Figure 3: Recorded setup used in the storyboard lecture. The lecture was live-streamed for animators, and the screen combined an iPad screencast of ProConte with a top-down camera view of the hands and pen.

object duration (20.4% of the total). Drawing timestamps span 52 production days; 36 of those days include activity across multiple storyboard files, and 13.8% of adjacent frames in first-drawing order moved backward relative to final episode order. The object records reflect the currently persisted state rather than user-attributed telemetry. Copied objects can duplicate timestamps, and summed per-object duration is not labor time.

The lecture board contains 119 production cuts, 416 final frames, 132 frame records in non-final clips or the Trash, seven exceptional final frames (1.7%), and seven Free Canvas frames; one Free Canvas frame retains 49 timed objects from an observed session. Our analysis associated 29,236 of 29,676 logged director drawing actions with 351 frames. The logged activity shows that 233 frames were revisited in non-contiguous runs and 70 on multiple observed dates. Transitions between finalized frames moved backward in final order 18.4% of the time. The measures exclude events not attributed to the director and later openings of the board.

Two trajectories illustrate how verbal and trace materials complement each other. The director repeatedly described the park layout, character routes, and poses as tentative early in the process. He explored paths around a slide on April 2, rejected an overhead view because it would distance the viewer from the action, and narrowed the chase into concrete screen direction and road-and-alley blocking. The records from that date show drawing activity across the umbrella catch, reverse traversal of the slide, retained umbrella, and alley chase. The director created alternative camera distances on March 12 and deferred selecting among them. He tried reversed cat-and-bag angles on March 20 and explained how low camera position and action simulation affected readability. One finalized frame from the cat-and-bag sequence was selected or edited across four observed dates, appearing in seven non-contiguous event runs with 502 logged drawing actions. The traces establish return and revision, while the verbal account supplies the situated reasons; neither establishes that another director would make the same choices.

A.4 Cross-Domain Conversations

To aid interpretation of the storyboard case, we also conducted two brief informal conversations with professionals in neighboring creative domains. Because these exchanges differed substantially in medium, language, and context, we do not treat their scale as directly comparable; one contribution came from an approximately 10-minute segment within a broader two-hour recorded discussion, while the other consisted of a several-hour asynchronous text-based exchange totaling roughly 5,000 Japanese characters.

One was a screenwriter in France with film-school training and a research background that included work on a UNESCO graphic novel about AI literacy. The other was a Japan-based manga artist whose work since a 2018 commercial debut includes two collected volumes, French and Italian editions, and short-form publications.

These conversations were not intended to validate the specific interface design of ProConte. Instead, they served as a limited source of triangulation by helping us assess whether issues such as non-linear development, selective carry-over, temporarily off-format materials, and staged commitment also arise in related forms of creative practice.