# Kaleidoscope: A Reflective Documentation Tool for a User Interface Design Course

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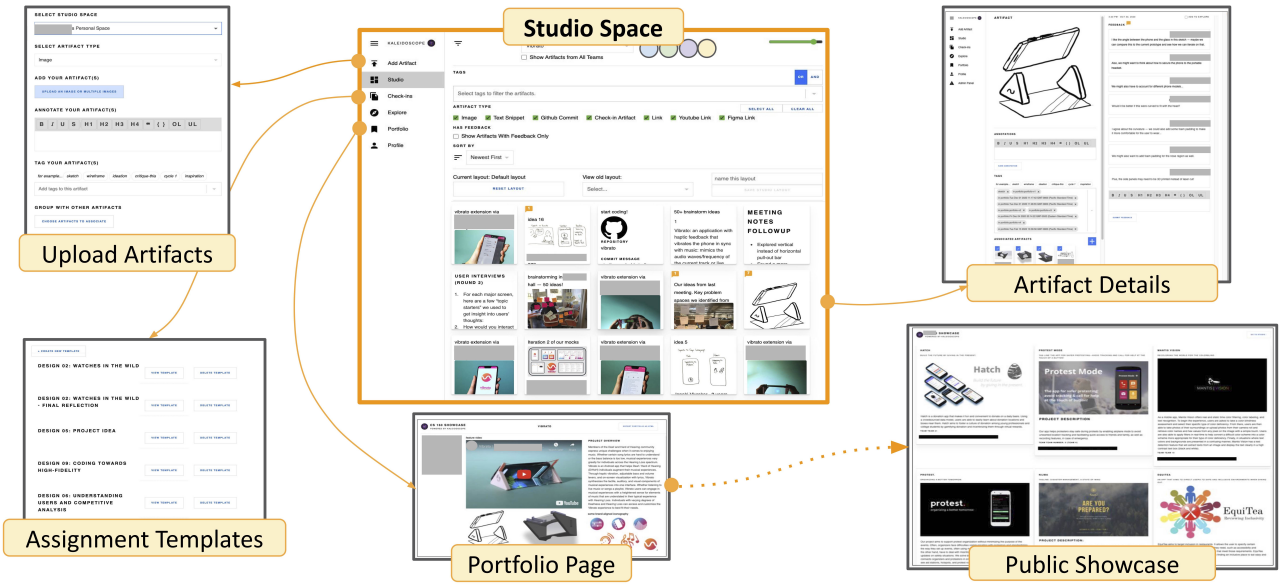


**Figure 1: Kaleidoscope is a remote collaboration tool for student teams in a project-based user interface design course. Group interaction centers in the "Studio Space," where groups document the history of their project with multimedia artifacts. Other features support assignment submission, peer feedback, portfolio creation, and instructor visibility into student process.**

## ABSTRACT

Documentation can support design work and create opportunities for learning and reflection. We explore how a novel documentation tool for a remote interaction design course provides insight into design process and integrates strategies from expert practice to support studio-style collaboration and reflection. Using Research through Design, we develop and deploy Kaleidoscope, an online tool for documenting design process, in an upper-level HCI class during the COVID-19 pandemic, iteratively developing it in response to student feedback and needs. We discuss key themes from the real-world deployment of Kaleidoscope, including: tensions between documentation and creation; effects of centralizing discussion; privacy and visibility in shared spaces; balancing evidence of achievement with feelings of overwhelm; and the effects of initial perceptions and incentives on tool usage. These successes and challenges provide insights to guide future tools for design documentation and HCI education that scaffold learning process as an equal partner to execution.



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## CCS CONCEPTS

• **Human-centered computing** → **Interactive systems and tools**; *Field studies.*

## KEYWORDS

HCI education, reflection, documentation, studio, online learning

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## 1 INTRODUCTION

Design education is a growing area of interest among the HCI research community. Since HCI is an interdisciplinary field, teaching HCI requires covering a complex array of concepts from multiple domains. Essential in this mix is *design process*: how designers perform, order, and cycle between tasks and actions in pursuit of a design goal. Many HCI educators teach some form of design as part of their HCI courses [55], and HCI itself can be seen as a fundamentally design-oriented practice [19]. While there are many ways to teach design, and multiple interpretations of "design process," a common approach is to use project-based learning and a studio environment to give hands-on experience in iteration, critique, and collaboration [44, 54]. There is no single prescriptive structure for successful design process [45], so project-based courses give students the opportunity to explore process for themselves, to try multiple approaches, and to adapt to changing needs.

At the University of California, Berkeley, such a course is the upper-level undergraduate User Interface Design and Development class. Though facility with the design process is a key learning goal of this course, instructors do not have a way to directly evaluate or view students' process. Instructors assess student projects based on the quality of individual assignment outputs; while these assignments represent key points in the design process – for instance, submitting preliminary sketches to demonstrate early ideation, then submitting wireframes to show progress and iteration — they capture only snapshots of outputs. Instructors only have access to these singular moments of students' process, which have been curated by the students to be "successful" submissions. Moreover, students themselves have limited visibility into the structure of their workflows even as they perform them. Without such visibility, students and instructors are limited in their ability to reflect on the design process itself.

One leverage point to make process more accessible to both instructors and students is documentation tools. Tools have significant effects on how practitioners approach process [16, 33]. Documentation tools in particular support not just individual tasks or post-hoc records, but are also active participants in the creative process, enabling iteration, branching ideas, and reuse of artifacts across the entire design process [26, 30, 40, 51]. In user interface design courses, students learn how to use specific tools for particular tasks (e.g. paper sketches for ideation, Figma for wireframing, slide decks for prototyping, etc.), but there is a gap for tools that support *reflecting* on the high-level aspects of process *across the entire design journey*. Documentation tools for design offer a unique opportunity to capture and reflect on process holistically while also supporting particular design skills.

In this paper, we ask three research questions:

(1) How can a documentation tool for user interface design make process visible to students and instructors for metacognitive reflection?
(2) How can a documentation tool directly support students' design process in collaborative interaction design projects?
(3) How can strategies from expert process be incorporated into tools for student learning?

We present a design documentation tool, called *Kaleidoscope* (Fig. 1), which we developed and deployed in the upper-level undergraduate user interface design course at our institution. Using Research through Design, we seek to understand how a process-focused documentation tool can support student design processes, group collaboration, and critical reflection on personal process. This work responds to the call for research in HCI education to provide empirical evidence from real classroom deployments [46]. In our deployment, students documented over 3800 artifacts in Kaleidoscope – design sketches, notes, photographs of prototypes, code, Figma documents, etc. – and left each other over 1000 pieces of feedback. These artifacts spanned many mediums, creating a central repository for project progress and infrastructure for feedback within and between teams. At the end of the semester, students used the tool to generate final portfolios from these artifacts for the class showcase. Student interactions with Kaleidoscope provided insights into the role of documentation tools in a course setting and shaped the design directions of Kaleidoscope as it was continuously developed throughout the semester in response to student needs, usage patterns, and feedback.

We deployed Kaleidoscope in a fully remote semester during the COVID-19 pandemic. Since this course is usually taught in an in-person studio format, this offered a chance to explore how a documentation tool might assist students in remote collaboration and go "beyond" replication of a studio environment, using the digital format to add greater depth and new interactions [25].

To guide the design of Kaleidoscope, we synthesized five key design principles from prior research on design process, education, and documentation tools: *collaboration, seeing the big picture, metacognition, curating the creative space*, and *making progress visible.* Through these design principles, the tool seeks to support the learning goals of the user interface design course, including *how to work together on team projects, how to give and receive feedback, the importance of iteration in design, how to communicate results, and how to design, prototype, and evaluate interfaces.* Tying together each of these specific learning goals is the role of reflection in learning; Kaleidoscope's key pedagogical philosophy is to support reflection on the design process as well as the design process itself.

We perform a thematic analysis of data collected across the semester, and discuss five key themes that arose from the tool's deployment: *tensions between documentation and creation, centralizing discussion, privacy and visibility in shared spaces, balancing evidence of achievement with feelings of overwhelm*, and the *effects of initial perceptions and incentives on tool usage.* Kaleidoscope acts as an interpretive artifact for investigating process-focused tool design, where our vision of more concrete histories of, reflection on, and evaluation of process can be explored and critiqued in real world use [22, 49, 58]. Successes and challenges with Kaleidoscope

provide insights to guide future tools for design education and process documentation, as well as for reflective documentation tools outside of educational contexts.

This paper contributes: (1) A novel documentation tool for user interface design courses. (2) A thematic analysis of student and instructor experiences, including how the tool supported the design process and shaped student learning experiences. (3) An annotated portfolio of the documentation tool as an artifact for shaping and reflecting on process.

# 2 RELATED WORK

## 2.1 HCI Education and Studio Learning Environments

Recent scholarship in the HCI community has increasingly investigated how research knowledge can improve HCI education, for example exploring a research agenda for HCI education [55], integrating research with reflections on teaching [45], and testing research theories in the classroom [46]. In this work, we use a Research through Design methodology [58] to introduce a new tool into a project-based user interface design course to better understand how to support student reflection, documentation, and collaborative process in an online setting.

In a survey of HCI educators, Wilcox et al. found that the vast majority of HCI courses include design in the curriculum (92% of respondents) [55]. We deployed Kaleidoscope in one of these such courses, which serves as both an introduction to HCI and to user interface design at our university. This course is heavily project-based, a common format for teaching design through practice. Students complete several group projects during the semester, culminating in a significant final project (see the Supplement for additional detail).

Studio environments are often essential to project-based design courses: they teach critique skills and reflection, enable learning-by-doing, and support peer interaction [44, 54]. Studio spaces make process visible through the physical presence of intentional artifacts and the detritus of process, which come together to ground learning and discussion [29]. Exploring how to bring studio interactions into the digital world, Koutsabasis et al. created a virtual studio in a 3D simulation environment where avatars can interact in group collaboration spaces [31], and found instructor awareness of student collaboration, real-time remote collaboration, and creative freedom to customize the group space as strengths of the virtual studio. Following from these works, we draw from the strengths of studio-based learning to design a custom tool for documenting and sharing design process in a fully remote design course.

This work was performed during the COVID-19 pandemic, which introduced new challenges to teaching and learning HCI. Roldan et al. report challenges as COVID interrupted their Spring 2020 HCI course, but also note opportunities such as easy recording of online meetings to support reviewing and reflecting on design behaviors [46]. Markel et al. explore design recommendations for experiential learning in the context of the pandemic [37], and Benabdallah et al. and Peek et al. both discuss the challenges of bringing hands-on making courses to remote contexts [6, 42]. We also sought opportunities within the challenges, designing Kaleidoscope not just to replicate features of in-person studios, but to provide additional capabilities to save process history, search and view multimedia design artifacts, and collaborate with teams.

## 2.2 Components of Design Process

The design of Kaleidoscope focuses on three specific elements of design process: documentation, reflection, and feedback.

*2.2.1 Documentation.* Documentation is an essential component of the creative process. The tools we use affect how we work and approach problems [16, 33], including tools for managing project histories. In domains from data science [26] to creative coding, tapestry weaving, and writing [51], to design history [30], the tools we use to document, visualize, and interact with history affect what and how we create. The same is true for education, where tools for documentation affect student behaviors. Chen et al. discuss how the structure of deliverables in design courses affected the types of documentation students created, and the way those types of documentation structured their understanding of design process into discrete stages [13]. Keune et al. show how tools for creating and sharing portfolios in makerspaces affect process, for example how providing a blog interface and specific times to journal helped a student integrate documentation into planning and creating new ideas [27]. Kaleidoscope draws from research on how documentation tools affect process to support specific strategies from expert practice in the classroom.

Documentation tools can also shape social and community norms, such as in Mosaic, an online community for sharing in-progress work that creates norms of feedback, reduces fear of sharing unfinished pieces, and supports reflection on process [28]. In studios, making past work visible and physical in a space enables transparency of process and constant critique and discussion [29]. Structures of documentation, including how writers store drafts or how ceramicists make work visible in a space, can shape responses to failure or error, creating more resilient and productive mindsets and community norms [53]. Kaleidoscope draws from these philosophies of transparency and the value of in-progress work to support remote collaboration and encourage norms that value process rather than only outcomes.

Information reuse is essential to the design process, where one's own prior work or that of colleagues is a key resource for inspiration and problem framing. Lupfer et al. discuss how interfaces for design history curation can support process through spatial organization across multiple scales of view [35, 36]. Annotated portfolios provide a way to capture a design history for a future audience, uncover underlying values, and communicate insights and learnings to a wider audience [21]. Designers keep many artifacts from the design process, relying on visual foraging to make sense of collections of artifacts [47], yet Sharmin et al. also note the difficulty of keeping artifacts connected to past design process [47]. Kaleidoscope seeks to support information reuse by acting as a central history repository across multimedia sources and providing context for the design history of artifacts.

Despite its importance, documentation can be difficult and underutilized. Documentation takes time and effort, and workplace value structures can deprioritize documentation in comparison to the speed of progress or generating new outputs. Specific materials or components of the design process can be harder to document

than others; da Rocha et al. explore the challenges and importance of documenting samples, noting their value for reproduction and communication, as well as the difficulties in interrupting a workflow to document and dedicating time to documentation [23]. In this work, we discuss challenges related to prioritizing documentation in a classroom setting and communicating its value to students.

*2.2.2 Reflection.* Reflection on design process helps designers and students improve how they work [45]. Roldan et al. introduce reflective activities into a studio design course, showing how structured reflection on past data can improve both design outcomes as well as students' understanding of their own process and what they might need to improve [46]. Roldan et al. focus on skills in participatory design sessions; we focus on longer-term patterns of design cycles and decision making. Feedback also plays a key role in reflection: it can be an anchor for reflection, and becomes more useful to the student when structured reflection is applied to the feedback itself [43]. Tools can help make process visible to students in order to structure these kinds of discussions and longer-term reflections [14, 34, 56]; Kaleidoscope seeks to make the design process visible to students by 1) collecting artifacts created across the entire design life cycle with many different tools and mediums into a single context, and 2) co-locating feedback on each specific artifact with the artifact itself as well as situated within the greater design context.

*2.2.3 Feedback.* Feedback is a key part of the student learning experience and the iterative design process. In the user interface design course we worked with in this project, feedback came from course staff, either as formative feedback during project work or at assessment points, from group members within a project group, and from peers outside the project group. Feedback contributes to the iterative design process, but also to students' metacognition around their own learning and process, in line with Boud et al.'s framing of students as active partners in the feedback process [8]. Feedback and critique can be hard to scale; Kulkarni et al. designed PeerStudio to provide scalable feedback in MOOCs by peers [32], and Tinapple et al. designed CritViz to support critique in large design courses, considering not just the logistics of critique but the social values of community, self-perception, and social accountability [52]. Similarly, Kaleidoscope seeks to support positive community dynamics and create visibility into peers' design process to allow peer-learning, while integrating feedback into a more comprehensive studio documentation tool. *Studio critique* or *design critique* is a specific form of feedback present in many studio-based HCI courses. Such critique sessions tend to be collaborative, interactive, and formative, fostering discussion among instructor and peers of the work under examination rather than evaluation [41, 44, 54]. As this project focuses on the role of documentation, we have chosen primarily to support written formative feedback within the tool, though the artifacts documented in the tool can be used in synchronous critique sessions. Direct support of interactive studio critique was beyond the scope of this paper, but combining specific strategies for studio critique with a documentation tool may be fruitful future work.

## 2.3 Digital Collaboration Tools in Our Classroom

Collaboration is essential to group work and successful design projects. Mercier et al. identify "creation of a joint problem space" as a key feature in successful collaboration in a design course, and emphasize the role of tools and shared artifacts in creating this space [38]. Kaleidoscope supports shared understanding by encouraging the central collection of all content related to the project, and acting as a shared reference for discussion and iteration.

Diverse collaboration tools have roles in the design classroom, in both in-person and remote offerings of courses. In the user interface design course we engaged with in this work, these include course support tools like Canvas [1], used for turning in assignments, hosting course media like PDFs of readings, and recording grades; or Piazza [4], a forum for questions and discussion. Students are taught to use Figma [2], a web tool for design layouts and wireframing (for a visual reference, see the Supplement), and turn in video demos of projects by uploading them to YouTube. During the pandemic, we also noted an increase in student use of other digital tools to support their group collaboration processes, such as Miro [3], a digital whiteboarding application for brainstorming and Google Drive, Docs, and Slides for live collaboration and organizing documents. Students also relied on messaging and video calling services like Zoom, Facebook Messenger, and Discord to communicate synchronously and asynchronously during group collaboration. Kaleidoscope seeks to fill a specific niche by focusing on design documentation and metacognition around process, incorporating or working alongside these tools rather than trying to replace them.

## 2.4 Action Research and Educational Deployments

Field deployments can provide real-world data from a large population of users in the environment of intended use [48]. In educational contexts in particular, Roldan et al. emphasize the importance of implementing and studying HCI research recommendations in real classrooms [46]. In this work, deploying Kaleidoscope in a semester-long design course allowed us to see how students used it in combination with other tools, during long-term projects, and with real group dynamics, and to investigate Kaleidoscope in relation to students' mindsets and stressors.

In particular, we draw from the philosophy of action research to guide this project [24]. In introducing a new tool into a classroom, we have multiple types of stakeholders: the students in the class, who have multifacted roles as learners, group collaborators, and designers; and the course staff, both the head instructor and the TAs who support the students through grading, mentorship, and lecturing. We engaged with both the teaching team and the students as a participatory community in the iterative design of Kaleidoscope. Action research can provide first-hand experience with practical applications of ideas, however, challenges around effort and time required make it less common than lab experiments and other research methods [39]. In the case of designing a tool for design education, we found it to be particularly appropriate to engage the students in the design and critique process.

Within the frame of action research, we apply a Research through Design methodology [57, 58]. Zimmerman et al. discuss four key

components of Research through Design: *process*, *invention*, *relevance*, and *extensibility* [58]. In documenting the *process* of this research work, we will present a system description, details of interactions and data collection with students that led to system design decisions, and a thematic analysis of qualitative data. Kaleidoscope presents *invention* through a novel multimedia documentation tool that supports remote design studio interactions and course requirements. Kaleidoscope allows students to investigate their own creative process at a metacognitive level, in contrast to prior literature and tools which support specific skills or detailed reflection. Kaleidoscope addresses questions of immediate *relevance* to the design community, as we continue to face remote teaching challenges related to the pandemic and broader cultural shifts towards online learning, and as the HCI community expands its interest in how to teach HCI and design most effectively. We hope that the community can *extend* the knowledge generated by this project to design future tools for creative documentation, consider new contexts for the role of reflection in learning design, and support remote learning in studio courses.

## 3 METHODS

In this project, we engaged in action research [24] through a Research through Design methodology [58]. Below we describe the course context, the design process with stakeholders including course staff and students, the Kaleidoscope system, and the method of evaluation. The long-term use and iterative design of Kaleidoscope within a real-world course context allowed us to support instructors and students during the transition to an online format for the user interface and design course at our institution during the COVID pandemic, while also allowing us to generate research knowledge through the expression, evolution, and evaluation of our design goals as instantiated by a real system.

### 3.1 Course Context

This project occurred in the context of an upper-level undergraduate HCI and user interface design course in the Computer Science department at the University of California, Berkeley, a large public university in the United States. This course covers user interface design, technical development skills, and HCI foundations; we will refer to it here as User Interface Design (UID). Between August and December 2020, this course was taught fully online for the first time, in response to the COVID-19 pandemic (see Supplement for additional details).

UID is a project-based course, with approximately 100 students, in which students learn a version of the design process that incorporates needfinding, prototyping, and evaluation techniques in an iterative cycle. The course is structured around multiple design projects across the semester, culminating in a two-month final project in which groups of four to five students design and implement a mobile application within the theme of "equity and inclusion." In standard offerings of this course, student project groups meet in-person to collaborate on design and implementation. The course also relies on in-person studio time, where students critique each other's work, test prototypes, and receive feedback. The remote offering of UID retained the project structure, but shifted all work online. Many students used Zoom and Discord for group meetings, Facebook Messenger for asynchronous communication, and Google Drive to collaborate in real time. Figma was a required tool for the course, which students used to brainstorm and create layouts and wireframes for prototypes.

Prior to the beginning of the Fall 2020 semester, the research team developed an initial version of Kaleidoscope, a functional documentation system for supporting collaboration and reflection. Throughout the semester, we continued to design and develop the system in response to its usage and student and instructor feedback.

We collaborated closely with course staff as key stakeholders in the design and use of a new classroom tool. two members of the research team were also members of the teaching team for this offering of UID, one as a teaching assistant, and one as the lecturer. A third member of the research team was a former lecturer for UID, and two members of the research team had taken a prior in-person offering of UID as students. Members of the teaching staff who were not research team members participated in discussions around the tool's role in the course, their experiences using it in their teaching, and desires and needs for its design.

As the second key group of stakeholders, students provided feedback and suggestions to the research team on their experiences and needs, reflected on their experiences, and communicated directly with the research team through feature requests, bug reports, and interviews. Kaleidoscope was introduced to students at the start of the semester as a documentation tool for group collaboration. In the How-To Guide on using Kaleidoscope, we describe it as follows:

> "While working on a project, designers often collect lots of images and examples as they build their vision for the final outcome. This tool allows designers to see everything collected in one place. This could help a designer to stay in touch with the original plan, try out new directions, and collaborate with others. This tool also lets designers look back at earlier iterations and see what's changed throughout the process."

The instructors demonstrated Kaleidoscope during a course section early in the semester, and encouraged students to integrate it into their design process, for instance by using it to share feedback and materials with their teams. The course required students to turn in certain assignments through Kaleidoscope; beyond that, there were no requirements about how students used Kaleidoscope in their process, and students created individual ways to integrate Kaleidoscope with other tools in their workflows.

Throughout the semester, we collected multiple types of data (see Section 3.4.1), investigating questions around the role of documentation tools in the HCI classroom, how to support remote studio environments, and how to encourage student reflection. All human subjects research activities were approved by our IRB. Participants volunteered for interviews through a recruitment form shared with all class members, and provided informed consent prior to each interview. Interviewees were compensated $15/hr for interviews. Students provided separate informed consent to allow the use of their private Kaleidoscope artifacts in research. To preserve student privacy, artifacts included in screenshots of the interface in this paper are illustrative examples created by the researchers, not student data. Figure 4 shows a screenshot of the final showcase for UID, which is publicly available online. De-identified responses from course surveys relevant to Kaleidoscope were analyzed as

secondary data. Usage statistics and student feedback on Kaleidoscope were never included in student grades. The two members of the research team who were concurrent course instructors did not participate in performing interviews, did not have access to consent data, and were not shown student interview data until after grades were submitted. Members of the research team who were not current staff had no access to any student course data beyond the data sources specified in Section 3.4.1, including no access to grades and non-Kaleidoscope assignments, such as reading responses and technical assessments. Mid-semester feedback was collected anonymously and responses related to Kaleidoscope were filtered from general course feedback by a course staff member before being provided to non-staff research team members.

## 3.2 Initial Design Principles

Documentation and history tools can shape creative process among expert practitioners, supporting particular strategies of reflection, motivation, and mindsets [40, 51]. In this project, we explore how such strategies might be introduced to design students through a creativity support tool. By drawing from strategies used by expert creative practitioners, we hoped to guide students towards building the skills they would need in the future. Through discussions with course staff and the research team, we identified specific strategies from prior research on design process, education, and documentation tools that might be relevant to the UID students and support the learning goals of the course.

This synthesis resulted in the guiding principles listed below, which informed the overall goal and initial design of the tool. We continually iterated on both the role of the tool in the course and the overall tool design throughout the semester, in partnership with students and instructional staff. The five guiding principles for our studio tool were: *metacognition, seeing the big picture, curating the creative space, making progress visible,* and *collaboration.* Below we describe each of these motivating principles, with example considerations and related theory, as well as connections to specific learning goals of UID (a complete list of learning goals can be found in the Supplement).

**Metacognition** – *Reflecting on how we learn and work can improve our process. Kaleidoscope should provide visibility into students' process so they can learn what works for them and what they might wish to change, by reflecting on both their own process and others'.* Metacognition and reflection has been suggested as important components of design education across a broad range of research: Rivard et al. propose reflexive learning as a framework for design education, emphasizing the value of critical reflection to learning design [45]. Roldan et al. explore how video can support structured reflection on student-led participatory design sessions in a design course [46]. Chen et al. use probes in a remote design course to encourage students to reflect on their documentation practices, and found that the majority of their participants valued documentation for supporting metacognitive processes [13]. Nicholas et al. show how embodying progress can support reflection as well as practitioner wellbeing [40]. Documentation tools particularly serve a role in metacognition: Yan et al. explored the benefits of visualizing version control histories for reflection in computer science courses [56], providing unique opportunities for students to reflect on how they approached writing code; Sterman et al. show how extended lifetimes of records can support reflection between projects and across long periods of incubation [51]. In UID, a foundational learning goal is to *design, prototype, and evaluate interfaces.* Metacognition helps students examine their processes in these domains and improve their skills and approaches through reflection.

**Seeing the Big Picture** –*Providing a high-level view of the project history can support design process, reflection, and understanding of progress. Kaleidoscope should provide a holistic view of design history, across all types of mediums and tools used in any stage of the design process.* Nicholas et al. and Sterman et al. show how access to artifacts from past stages of the creative process support future work, by anchoring work to enable future exploration, maintaining an active palette of materials, and supporting reflection and motivation [40, 51]. Sharmin et al. explore the value of re-use of artifacts particularly in design activities [47]; Klemmer et al. discuss the value of visibility of artifacts in studio and workshop contexts to enable communication and coordination as well as situated learning [29]. Studying design documentation at multiple scales of view, Lupfer et al. show the value of high-level views of design documentation to exploring and communicating ideas [35, 36]. As a design documentation tool, Kaleidoscope draws on multiscale approaches to representing history, and should support visual foraging and building on older artifacts. High-level views align with the learning goal of understanding the *importance of iterative design for usability* by allowing students to more easily build on prior artifacts and flexibly iterate. In supporting communication and coordination, this principle also addresses learning goals including how to *communicate your results to a group* and *work together on a team project.*

**Curating the Creative Space** – *The character of the studio space affects designers' mindsets, bricolage practice, and feelings of ownership. Kaleidoscope should allow users to hide artifacts, draw attention to artifacts, and personalize the space.* Klemmer et al. describe how the artifacts present in design studios provide aesthetic and structural features to support peer learning, discussion, and critique in educational design contexts [29]. Similar benefits occur across creative domains, where practitioners deliberately curate their creative spaces to be surrounded by inspirational artifacts, such as their own past work or others' [40, 51]. In constructing a design studio in a 3D virtual world, Koutsabasis et al. found the ability to construct and decorate their virtual collaboration space was engaging for student groups [31], and Nicholas et al. discuss how "aestheticizing" can create personal motivation for creative activities by increasing the sense of value of an artifact and a desire to return to it [40]. Curation of the space can support learning goals including *work together on a team project* and *give and receive feedback as part of design iteration.*

**Making Progress Visible** – *Mindsets affect confidence, self-efficacy, and perceptions of success. Kaleidoscope should allow students to see progress made on a project and have easy access to work of which they are proud.* In Mosaic, Kim et al. demonstrate how sharing works-in-progress supports productive mindsets around learning, improvement, and the value of process, as opposed to placing all value on final outputs [28]; similarly, Nicholas et al. show motivational benefits from embodying progress [40]. Especially in a domain like design, where failure is an inherent part of the process [45], growth mindsets [18] and valuing process over final output

should be essential learning goals for design courses. Not only does growth mindset underlie UID's teaching team's philosophy of teaching and learning design, a focus on progress helps support the learning goal of understanding *the importance of iterative design for usability*, drawing student attention to how designs improve over time.

**Collaboration** – *Working with a team is integral to design and to the structure of UID. Kaleidoscope should provide context for decisions, support communication, and allow teams to get feedback on the project as a whole or on specific artifacts.* Mercier et al. discuss the importance of a "joint problem space" for group collaboration, where members can concretize ideas and share context for deliverables and decisions [38]. CritViz, a system for structuring peer feedback in creative classes like a design class, shows how giving and receiving feedback leads to better outputs and creates a sense of community and teamwork [52]. Several learning goals of UID focus on teamwork, including how to *work together on a team project*, *ability to give and receive feedback as part of design iteration*, and how to *communicate your results to a group*.

## 3.3 Kaleidoscope System

Kaleidoscope is an online collaboration tool for documenting design history, supporting student reflections on their design process, and providing features for design education (Fig. 1). Kaleidoscope is written in React, and uses Google Firebase for database and server hosting. Students use their institutional Google accounts to log in to Kaleidoscope.

*3.3.1 Studio Spaces.* The central feature of Kaleidoscope is the "Studio Space," where individuals or groups collect and display artifacts from their project work (Fig. 2). Each group has its own studio space for each class project; an individual can only see and edit spaces of which they are a member.

Users can upload *artifacts* to a studio space, where they are displayed as thumbnails. Artifacts can be images, text, GitHub commits, or links to other webpages, with special support for YouTube videos and Figma layouts. These covered the core types of information created for the class, with physical sketches and prototypes documented through photographs and videos. Initially, studio spaces displayed artifacts in an automatic grid layout; later iteration introduced a whiteboard-style free-form layout feature, where students can rearrange artifacts and save layout histories (Fig. 2).

Artifacts can be *tagged* with free-text or suggested tags during upload or later on, to track particular design stages, assignments, or ideas. Artifacts can also be *associated* with each other, to form conceptual groups between separate artifacts. Artifacts are displayed in the studio space, where they can be sorted and searched. They can be viewed individually on a *detail page*, containing the artifact, tags, description, title, and associated artifacts (Fig. 3). Detail pages also display *feedback* from group members, course staff, and other students. On the studio page, an icon in the corner of the artifact indicates the amount of feedback on the artifact. Artifacts can be kept private to the team and course staff, or made public for any student to view and leave feedback.

*3.3.2 Course Tools.* Certain features were designed specifically to support Kaleidoscope's role as a tool for UID.

*Check-ins* are a special type of artifact, used for submissions of course assignments. A check-in template lists the requirements for the assignment; students can select particular artifacts to include for each requirement. Check-ins are not displayed in the studio, but can be accessed through a separate page for templates and check-ins.

The *Explore Page* displays artifacts that groups decide to make public. Instructors can make artifacts submitted with assignment check-ins public, allowing them to curate galleries of student work: for example, collecting all low-fidelity sketches from an assignment and sharing this view with all students. In this way, students can see and learn from peer work, similar to how they would in a physical studio environment.

At the end of the semester, students participated in a design showcase to publicly present their work. To support the virtual version of this event, and to help students create a portfolio-style summary of their project, *Portfolio Pages* allows students to arrange artifacts in a curated, public-facing layout (Fig. 4).

*3.3.3 Design Iterations.* Over the course of the semester, the research team solicited feedback from students, spoke with course instructors, and monitored bug reports and feature requests from students. We analyzed and discussed feedback and student use behaviors as they were collected. We continuously updated the tool, adding new features and fixing bugs in response to student needs while aligning the tool more effectively with the design goals. Two major updates were *editable artifacts* and *customizeable layouts*.

Initially, all artifacts were uneditable. Once uploaded, they acted as a static archive of the design history. Deleting artifacts was possible, but not recommended. However, students were frustrated by small errors in text artifacts that then had to be re-created to fix, and wanted to be able to work with teammates to update text artifacts after they were created. This resulted in an evolution of our design goals, where the initial conception of Kaleidoscope as a static archive was relaxed to support students' needs to co-locate creating and editing content as well as documenting it. In response, we introduced a rich text editor to the text artifact detail pages, allowing changes to text artifacts.

The initial studio space layout was a column-based layout of artifacts, running left to right in chronological order from most recent to oldest. Artifact tiles had a fixed width, which could be adjusted for all artifacts at the same time by a slider. Each artifact took the least amount of vertical space it needed to be completely visible, and so tiles varied in length. Students found this layout messy and hard to search. They expressed desire for customizeable arrangements in order to explore ideas and more actively interact with the design history during brainstorming and group discussions. In response, we introduced *layouts*, a grid-based default view in which artifacts could be resized, moved, or hidden from a view (Fig. 2). Layouts could be saved with custom names and timestamps, and easily reloaded from a dropdown menu.

Other changes included bug fixes, support for additional artifact types, and the end-of-semester portfolio feature (Sec. 3.3.2).

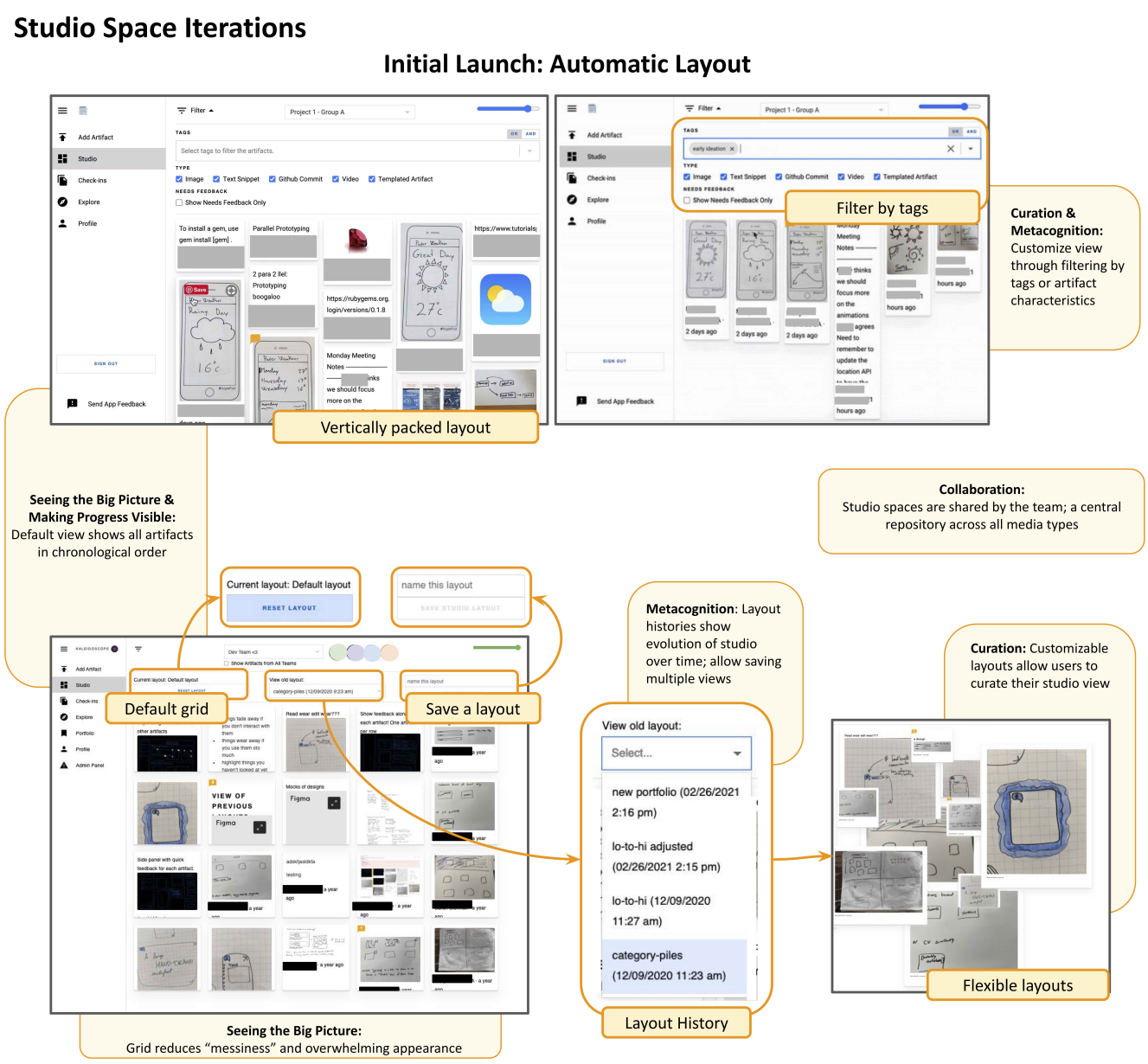


**Figure 2: We iterated on the Studio Space design throughout the course. We began with the design on the top, where artifacts are automatically organized chronologically to show development over time. Filtering on tags (top right) surfaced particular artifacts and allowed focused comparison across topics. Around the middle of the semester, we released flexible layouts for the studio spaces. Artifacts in the default grid (bottom left) were square aspect ratios, creating a neater initial view. Artifacts could be resized and moved freely (bottom right), and the custom views saved in a dropdown list for later review or editing (bottom center). Filtering by tags is also supported in the custom view. (Artifacts shown in screenshots are hypothetical data to demonstrate the interface.)**

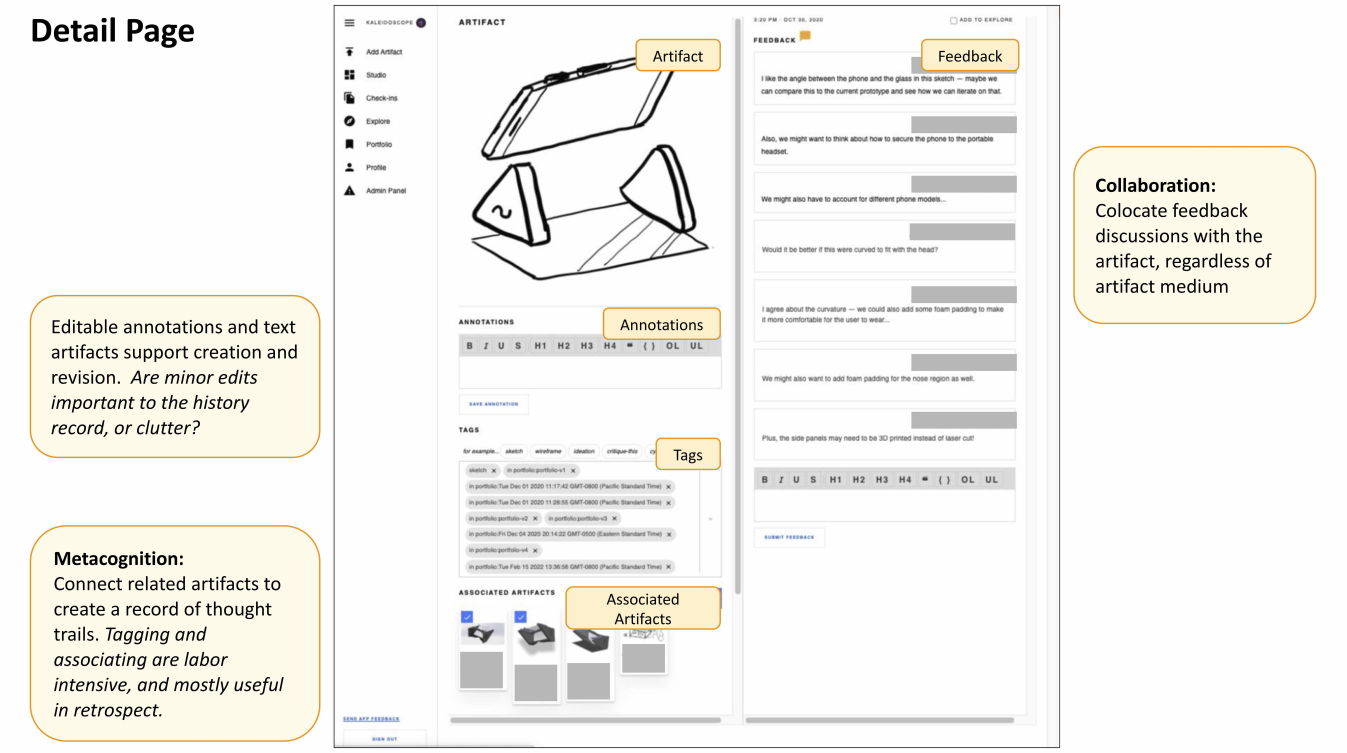


**Figure 3: The Artifact Detail page shows information related to a specific artifact: the artifact itself, in this case a design sketch; an editable text annotation; the history of group discussion and feedback on this artifact; tags applied to the artifact; a tile view of associated artifacts for this artifact. (Artifacts shown in screenshots are hypothetical data to demonstrate the interface.)**

## 3.4 Evaluation Methods

*3.4.1 Data Collection.* As Kaleidoscope was integrated with UID throughout the semester, we had access to a breadth of data collection methods, including course assignments, reflections, and feedback surveys, as well as sources specific to the research project, including semi-structured interviews with student volunteers. This breadth of data types allowed us to learn about how Kaleidoscope was used and received through multiple contexts throughout the semester. Data collected during the semester was used to guide the iterative design of Kaleidoscope.

(1) *Mid-semester semi-structured interviews (N=5).* Near the midpoint of the semester, the research team performed semi-structured interviews with individual students on their design process during the course, reflections on learning design, and the role of Kaleidoscope in process and learning. The interviews were performed by non-instructor members of the research team. Interviews began by discussing where the students were in the course, what stage of the current project they were in, and how they felt the project was going. Interviews then transitioned to specific questions about personal and group workflows and their usage of Kaleidoscope. Following standard semi-structured qualitative interview techniques [11, 12], the questions evolved within and between interviews; a representative selection of guiding questions can be found in the Supplement. Students volunteered for interviews, and provided separate informed consent to interview procedures. Interviews were recorded for transcription purposes. Participants were compensated at $15/hr; interviews ranged between 45 minutes and 2 hours. The identities of interview participants were not disclosed to members of the teaching team, and had no effect on course grades.

(2) *Mid-semester course survey (N=34 students mentioned Kaleidoscope).* The course staff released an anonymous mid-semester course survey in which students reflected on the class overall and gave feedback on what was going well and what could be improved, as a standard part of UID. A member of the course staff filtered survey responses for responses related to Kaleidoscope before providing them to the research team. The text of questions containing responses mentioning Kaleidoscope can be found in the Supplement.

(3) *Design reflection extra credit assignment (N=55).* Near the middle of the semester, the teaching staff released an optional extra credit assignment in which students could reflect on their design process so far. Optional extra credit assignments during the semester in which students reflect on their design process and teamwork are a standard part of UID. The assignment came from the teaching staff as part of the course and did not mention Kaleidoscope in the instructions or the questions. The data were de-identified and analyzed as secondary data. Extra credit was given to all respondents,

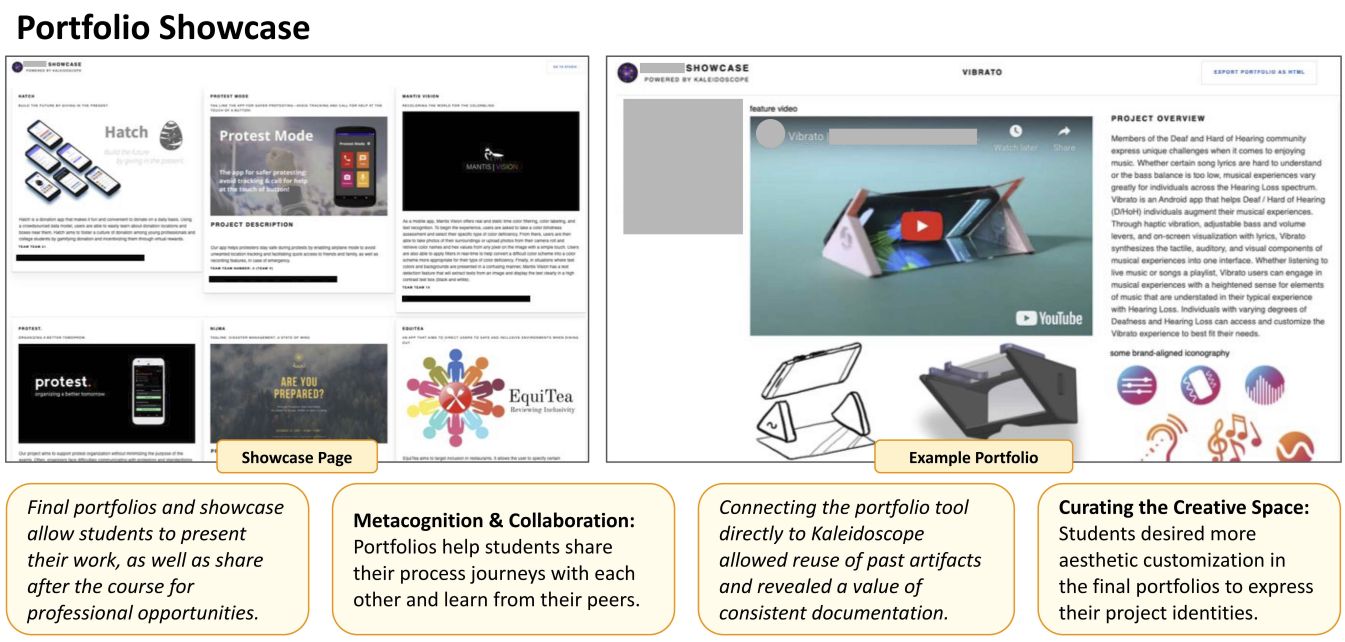


**Figure 4: Portfolio Pages. At the end of the semester, students created interactive portfolios from their artifacts (hypothetical example to demonstrate the interface at right). Portfolios were collected as part of a publicly available online showcase (left).**

with no evaluation of "correct" or "incorrect" answers. The goals of the assignment were: to describe and discuss your own creative process; make explicit any subconscious behaviors and themes that affect your process; reflect on potential improvements to your process for future projects; and consider how tools can support your learning, creativity, and reflections. While the questions did not explicitly reference Kaleidoscope, many students discussed the tool's role in their process. The instructions for and questions presented in the survey can be found in the Supplement.

(4) *Kaleidoscope critique session (N=18).* In the middle of the semester, we moderated a voluntary critique session during which small groups of students discussed their biggest frustrations with and wishes for Kaleidoscope in a focus group for which participants provided consent. Students were given five minutes to individually add thoughts in a shared Google Doc, in response to questions about their experiences with Kaleidoscope (details in the Supplement). Next, groups took five minutes to read others' comments and add followups. Sessions concluded with 15 minutes of open discussion moderated by a single researcher, who took de-identified notes on student responses, with no recordings or other identifiable data.

(5) *Post-semester semi-structured interviews (N=7).* Post-semester semi-structured interviews with students focused on their design process during the course, reflections on learning design, and the role of Kaleidoscope in process and learning (performed by non-instructor members of the research team). Interviews began by discussing general reflections on the course, before transitioning to specific questions about usage of Kaleidoscope. As semi-structured interviews, the questions evolved within and between interviews; a representative selection of guiding questions can be found in the Supplement. Interview consent and compensation protocols were the same as for midsemester interviews.

(6) *Meetings with course staff (N=3 course staff, not including members of the research team).* Throughout the semester, we held meetings with course staff to discuss their usage of the tool and their perceptions of student experience, and took detailed notes of the conversations.

(7) *Bug reports and feature requests.* We collected bug reports and feature requests from students during the semester through a Google Form linked directly from the Kaleidoscope page, through direct emails, and Piazza posts.

(8) *Usage data.* We collected all materials uploaded to Kaleidoscope, and logged interactions on the platform. Over the course of the semester, 149 users across 181 teams created 3268 artifacts, including 1063 images (33%), 1892 text artifacts (58%), 116 GitHub commits (4%), 89 YouTube videos (3%), 64 Figma layouts (2%), and 44 other web page links (1%) (Fig. 5). 1077 individual pieces of feedback were left on artifacts. 553 check-ins were created for course assignments.

*3.4.2 Analysis.* During the deployment semester, the research team held weekly meetings where we discussed data collected so far, including student and course staff's experiences using the tool, and newly requested features and bugs. We used these meetings to guide the direction of tool development and reflect on the tool design, role, and student experience. After the semester, we performed a thematic analysis of the qualitative data from the sources described in Section 3.4.1. We first transcribed all interviews and critique

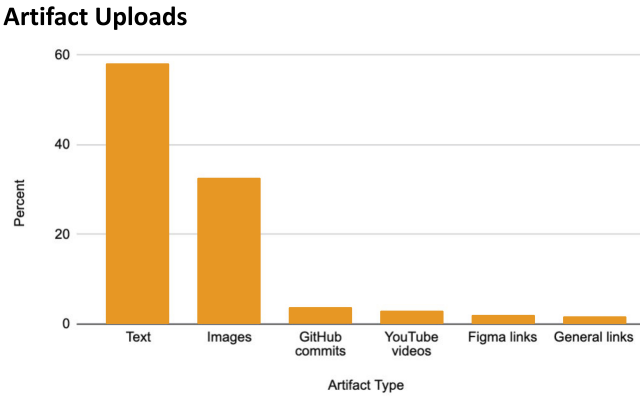


**Figure 5: Types of artifacts uploaded to Kaleidoscope. 3,268 artifacts were created during the semester.**

sessions, and extracted all responses from surveys and instructor meeting notes. Two researchers iteratively applied open coding to all of the combined corpus, creating an initial set of low level descriptive codes. We then grouped the codes into higher-level themes, creating memos that incorporated the descriptive codes, quotes, and emergent concepts. In a reflexive process, we reapplied the higher-level codes to the corpus and refined the codes and memos. We are specifically interested in analyzing Kaleidoscope as a Research through Design artifact within the frame of process-sensitive creativity support tools [50]. Therefore we focus our findings and discussion on interpreting the effects the Kaleidoscope system had on student experience and learning, including changes across the iterative development of the tool.

We present findings from the thematic analysis below. We do not report participant counts for themes, as semi-structured and evolving interviews meant not every participant was asked identical questions, and reporting 'counts' is not appropriate for this type of reflexive qualitative methodology [9, 10]. Additionally, we draw from the concept of Annotated Portfolios to present this work, demonstrating design decisions through annotated figures [21].

## 4 FINDINGS

In this section, we discuss the themes identified through our thematic analysis. Several of these themes explore tensions within the tool, where particular design choices enabled beneficial uses while at the same time creating challenges. Table 1 organizes these successes and challenges by Kaleidoscope's initial design principles.

### 4.1 Documentation Supports Reflection, Conflicts with Creation

Kaleidoscope was designed as a tool for documentation. The archival nature of Kaleidoscope supported metacognitive reflection, providing a benefit long after the act of creation itself. However, there was a tension between these later benefits and the immediate labor of artifact creation.

As a documentation tool, Kaleidoscope's design began with an archival approach to artifacts, in which artifacts were kept long-term without editing. While editing of text artifacts was introduced later in the semester, it was mostly used for minor, temporally proximal changes, and most artifacts remained static. This artifact-focused, archival design choice allowed students to collect a history of past ideas in the studio space. By keeping these visible to the team, the artifacts showed how the project developed over time and allowed students to reflect on their process at a high level:

> I tend to think of Kaleidoscope as timestamps of my creative thinking. It was great to see how my ideas were evolving over time. *(Anon - Critique Session)*

The design choice to present artifacts as a collection of visual tiles allowed students to quickly page in past context and stages of work:

> It facilitates my thinking process... By reviewing Kaleidoscope, it reminds me of the designing process quickly. *(S67 - Reflection Assignment)*

Students were prompted to carry out an explicit reflection on their creative process midway through the semester. While the assignment did not mention Kaleidoscope, many students reported using Kaleidoscope to reflect on their project history:

> [For the reflection assignment] I definitely took a look at my previous sketches in kaleidoscope. Which [at the start] did not seem like a great tool, but looking back really changed the way I looked at it. It almost feels like a version control for prototyping. *(S103 - Reflection Assignment)*

Aside from ad-hoc or prompted reflection, the final assignment encouraged additional reflection. Creating a portfolio to collect both final outputs and show a retrospective on process is a standard technique in design classes. When creating their final portfolios within Kaleidoscope, students were able to use the history of the project already collected in Kaleidoscope to reveal their design process and help their peers learn from their process:

> A lot of the artifacts that we added [to our portfolio] were actually artifacts that we already had... we wanted to include that step of the process to help inform other people's processes as well. *(S50 - End Semester Interview)*

Yet the very design choices that supported these types of reflection also interrupted creation and made it less likely that students would pause to save an artifact. When students were creating content, they had to work in other tools. This student described why they chose not to create an artifact in Kaleidoscope:

> I could have created an artifact in Kaleidoscope. But why do that when I want people to go to Figma and make edits? *(S47 - End Semester Interview)*

The archival nature of Kaleidoscope, where a Figma wireframe might have been contextualized with artifacts from other mediums, might have supported long term reflection. However in the moment of creation, using Kaleidoscope would have split teammates' attention between two platforms, making it less likely for them to make direct contributions to the current task.

Students added artifacts to Kaleidoscope most commonly for assignment submissions, and group discussion. Other parts of the project history were left in other tools, for instance snapshots of edits in Figma were rarely incorporated into Kaleidoscope. Instead, the artifact was added to Kaleidoscope only when it was considered "finished." Stopping to create intermediate artifacts required a change in focus from "creating" to "documenting":

| Design Principle | Kaleidoscope Features | Successes | Challenges |
|---|---|---|---|
| Collaboration | studio space; feedback | central repository of team data; ability to collect multi-source artifacts; sharing peer feedback | lack of live collaboration; discomfort with making artifacts public to team; discomfort with permanence of artifacts |
| Seeing the Big Picture | tile display of artifacts; setting artifacts to public | visual display enables high-level views; peer learning about process | visual display can be messy, overwhelming, disorganized |
| Metacognition | archive of process history | support post-hoc reflection; understand process through documentation | tension between modes of 'creation' and 'documentation' reduces storing of history |
| Curating Creative Space | flexible layouts | customization of views; active interaction with history data | lack of personalization; lack of aesthetic control |
| Making Progress Visible | tile display of artifacts; studio space | see progress through artifact accumulation; see evidence of teamwork; see idea development | bugs and system limitations created frustration |

**Table 1: Summary of qualitative insights, organized by the design principles of Kaleidoscope, to inform future design process documentation tools for education.**

> I would like to have things more documented...but it's really hard because in the moment you don't know when you're going to change things...When I create things, I want them to be the final version. So I don't think "Oh, I should document this right now", because it's either 1) it sucks, and I don't want to document it, or 2) it's good, and then it'll stay around. *(S47 - End Semester Interview)*

Despite the hurdles to capturing-during-creation, students expressed a wish for easy access to those intermediate histories after the fact. For example, students found value in viewing multiple drafts of Figma documents in parallel, to see the variation between design options. In contrast, they experienced frustration with how hidden past versions are in Google Docs. They found the centralized history in Kaleidoscope helpful for reflections and creating final documentation. Yet these benefits were often realized only in retrospect; in the moment, students did not want to be removed from the activities of creation or to put their teammates in a reflective rather than generative mindset, or they did not know at the time when a change was important enough to be worth the disruption to document it. Without intermediate artifact states, metacognitive reflection is harder; yet capturing intermediate states is disruptive.

## 4.2 Centralizing Discussion

Feedback was one of the most successful and well-received features of Kaleidoscope by students, however instructors felt pressure not to share potentially negative feedback in a public setting. In this section, we explore both student and teaching team reactions to centralizing discussions.

*Students:* Students appreciated the parallel viewing of artifacts and feedback, the ability to rapidly see how many people had left feedback on an artifact from the main studio page, and the permanence of discussions. In cases where groups did not use Kaleidoscope's feedback features, conversations were often buried in chat logs or scattered across document types. Kaleidoscope co-located group discussions, feedback from TAs, and feedback from peers with the project history, so that discussion and decision points were easily accessible and contextualized by the artifacts.

Beyond ease of access, making artifacts public to other classmates for review and feedback helped students learn from each other's process:

> There were the times that we would do the feedback for people's artifacts ...it not only allowed me to inform people about what our team had done and see if that could potentially help provide any additional help for that team or any additional inspiration, but also our team ourselves got inspiration from what other people had to say on ours...I really did value the time that I got to look at other people's portfolios [and] look at other people's artifacts. *(S50 - End Semester Interview)*

We designed an additional feature for sharing artifacts and feedback with classmates, called the "Explore Page," where students could browse public artifacts from their peers on particular tags. For example, they might view a gallery of "early ideation" to see how other groups were approaching that stage of the process. However, this feature contained significant bugs for most of the semester, and we were unable to collect sufficient data on how it was used.

*Teaching Team:* Like the students, TAs also appreciated being able to see student comments on the artifacts, providing insight into the group's process and discussions. Such discussions were otherwise invisible to the teaching staff, as they took place in private or ephemeral channels such as group notes documents or messaging applications. Visibility helped both students and instructors access, understand, and critique process.

One challenge of centralized feedback was that TAs did not feel comfortable sharing feedback that might be interpreted as negative or critical in a public area, despite the importance of critical feedback to learning. While TAs shared their positive feedback for students within the Kaleidoscope interface, they used our institution's Canvas platform for critical feedback, or comments related to grading. Separating critical feedback from positive feedback may skew students' ability to learn from peers' work, and remains a complex challenge related to privacy and visibility.

### 4.3 Privacy and Visibility in a Shared Space

Besides tensions around what types of feedback should be public, the shared nature of a Kaleidoscope studio space both supported and stymied group collaboration and communication, with tensions between wanting to have access to teammates' work and progress, and desiring privacy during individual creation.

Teams developed personal structures for managing collaboration and project state, some relying on tools like Google Drive, and some on Kaleidoscope; many groups used a combination of multiple tools. Kaleidoscope's studio space was particularly beneficial to managing team state and communication, since it combined materials from many different sources along with design discussions:

> It [Kaleidoscope] keeps all of our work together and we can always refer to our studio. *(S79 - Reflection Assignment)*

> We documented every design we had. And we put almost all our design discussion in kaleidoscope. Whenever I need to look for something, I would first check kaleidoscope. *(S32 - Reflection Assignment)*

Students who didn't use Kaleidoscope found it more challenging to maintain an awareness of the team's state:

> It's hard to measure progress because I think also people do things on their own and then they ported over [to a shared Google Doc] just like I did...So it's hard to see how people are progressing and what they're thinking or where they are in their parts of the project. *(S117 - Midsemester Interview)*

However, studio spaces created a tension between individual and team work, or private and public artifacts. Many students only wanted team members to see polished or completed artifacts, and held personal parts of the process back.

> If I think that someone else is going to see it, it often hinders my ability to be as honest about whatever my ideas are or thoughts are. *(S47 - Midsemester Interview)*

Since other group members could see them, artifacts in the studio space felt more "permanent" (S47 - Midsemester Interview), and the inability to edit them made them feel "set in stone" (S42 - Midsemester Interview). Kaleidoscope therefore failed to capture evidence of the design process that students felt was in-progress or individual.

These student reactions led to many discussions within the research team about design decisions related to visibility in the tool. The original design had assumed that group members would be comfortable sharing artifacts among themselves, but would desire privacy from peers outside of their group. Yet even within groups, students felt pressure to share only polished work with each other. This undermined the goal of Kaleidoscope as a complete record of process; to make a more effective shared record of progress will require careful sensitivity to the balance between privacy and visibility even among group members.

Visibility makes many types of learning possible – reflecting on complete histories of your own team's process, learning from other students, and providing instructional staff insight into how the students are learning so they can provide better instruction. Yet fear of judgment and criticism reduces how much people are willing to share in a visible space, even knowing the goals of a complete archive. Addressing this tension will require careful design choices. One direction might extend the idea of low-fidelity versioning from [51], so that team members can see that certain artifacts have been created by other members, but not the details, or creating temporarily private sections of the studio so that individuals can work privately before sharing. However, resolving this tension will also require deeper investigation into the motivational and mindset aspects of why students are unwilling to share certain artifacts and reshaping the social and team structures that cause fear of judgment or criticism.

### 4.4 History Display Creates Sense of Achievement but also Overwhelms

The tile display of artifacts in the studio space allowed students to see their project at a high level. At the same time, the same design choice could be overwhelming as more and more artifacts were added to the space.

Seeing artifacts collecting in the studio space helped make progress visible, and created a sense of achievement:

> I also saw that with Kaleidoscope, seeing at the very beginning, you have your artifacts that you created with your team ...and then you start innovating and as you kind of look back at the check in artifacts or the feedback that you get from people, you kind of see we're making pretty good progress and we've come a long way from where we started. And that's really cool. *(S50 - End Semester Interview)*

> [Kaleidoscope is] used to help document the iteration process, which can often be really empowering for teams. *(Anon - Critique Session)*

In contrast, the histories in tools like Google Docs are more hidden: edited or changed materials disappear unless explicitly sought out in a separate history tab, and can only be viewed one at a time. Students did not get the same satisfaction in progress or team awareness in tools like Google Docs as in the visible Kaleidoscope history:

> I think the fact that you can see an artifact is kind of like a accomplishment...versus a Google Doc or Google Slides [is] just a chunk of documents put together...It's kind of fulfilling and rewarding, you actually came a long way as a team. *(S42 - Midsemester Interview)*

> It's nice to be able to scroll through and see our project's journey. Some of these things I've since forgotten so I love the visual aspect of Kaleidoscope that allows me to easily refresh my memory. *(S13 - Reflection Assignment)*

Since creative design is an underspecified, complex task where it can be hard to see a path to "success" while embedded in the process, making effort and progress visible to students can be an essential part of motivating students and building a sense of self-efficacy and forward progress.

But the visual layout was also a challenge, especially initially when the layout was automatically generated. Many students found it messy and overwhelming:

> I don't really like the Kaleidoscope interface. I find it to be very messy. *(Anon - Critique Session)*

> When I first go into Kaleidoscope, I'm greeted by a wall of all my artifacts and that's a little bit overwhelming for me. *(S117 - Midsemester Interview)*

Some students preferred to *store* artifacts in Kaleidoscope, but *organize* their artifacts in less "messy" interfaces. One team used Kaleidoscope's Detail pages, where feedback and annotations were co-located with the artifacts, for discussion and archiving, then copied direct links to the Detail pages into a Google Doc, which they found easier to manage and search. A common request during the early part of the semester was for more organization abilities in Kaleidoscope, for example a folder structure, to sort artifacts into conceptual groups and hide artifacts that were deemed no longer relevant. The introduction of flexible and saveable layouts partially addressed this need, but especially for students who characterized themselves as particularly neat or organization-focused, the lack of structure drove them away from Kaleidoscope. To benefit from seeing the entire project at once, they also needed to hide artifacts.

## 4.5 Initial Perceptions and Incentives

As a research tool under active development during the course, Kaleidoscope was less stable and polished than commercial tools that students are used to working with. The research team kept a tight response cycle on addressing bugs, listening to student feedback, and incorporating new features, however Kaleidoscope had some severe bugs during its deployment, including a case where feedback was overwritten in the database after being submitted. While this was rapidly fixed, it undermined student trust in the system, which persisted after the issue was resolved. Some students cited specific bugs or problems with the visual layout as reasons they used other tools rather than Kaleidoscope, or the general difficulty of using a less polished tool:

> There were moments where my project team and I thought about just dropping random thoughts/artifacts into our studio that made me realize how great [Kaleidoscope] could be as a collaborative tool. We never ended up doing so because it was just easier to do on Google Docs even if it was messier. *(Anon - Critique Session)*

Beyond practical issues with the system, a second challenge arose with student perceptions of the role of the tool. Check-ins were developed as a way to make assignment submissions easier; the reasoning was that if all the material is already in Kaleidoscope, picking specific artifacts to submit should be easier than exporting materials to assemble in another tool and then uploading that result to Canvas (UID's course management system). Moreover, check-ins on Kaleidoscope support easy sharing of artifacts for feedback and peer-learning, since artifacts in check-ins can be grouped together and made public by the instructors. However, the use of check-ins for assignments fostered an early perception that Kaleidoscope was a *submission* platform, rather than a tool for design work. Some student groups began to use Kaleidoscope only for submissions, importing artifacts only when they needed to submit a check-in.

The combination of bugs and hard-to-use interface aspects, along with the perception of Kaleidoscope as a submission system, discouraged some students from interacting with it, even after the bugs and interface issues were fixed or improved. Once the early perceptions were established, they were hard to change.

> I think those initial weeks really colored a lot of our perceptions of what Kaleidoscope was possible of, and because we had already found alternative ways to work by the time Kaleidoscope start addressing those issues, it was just harder to then switch back. *(S126 - End Semester Interview)*

Portfolios ended up being a highly successful feature at the end of the semester, where the motivation for having all artifacts and project history centrally available was clear and aligned with both course assessment requirements and students' intrinsic motivations for showcasing their work. UID was many students' first exposure to design; the first time through the design process, students did not realize or appreciate the value of an early sketch or idea until they wanted to include it in an assignment or final presentation.

> If we had to change the way we record information, I would put more materials into Kaleidoscope initially. *(S18 - Reflection Assignment)*

In introducing a research tool into a course setting, early student interactions should be carefully aligned with desired perceptions and uses of the tool. In our case, aligning with the tool's value to the design process and reflection should have preceded any assignment submissions with the platform.

# 5 DISCUSSION

Having explored themes of how students interacted with Kaleidoscope in Section 4, we now turn to discussing Kaleidoscope from a pedagogical perspective, in relation to research literature around education and expert practice.

## 5.1 Documentation Enables Explicit and Opportunistic Reflection on Process

In this research, we asked *How can a documentation tool for user interface design make process visible to students and instructors for metacognitive reflection?* Key learning goals of UID included learning to design, prototype, evaluate, and iterate on interfaces; these skills combine into an overall 'design process.' Reflection can provide students opportunities to consider successes and improvements to their process. Here we discuss the design choices of Kaleidoscope that enabled different types of reflection: explicit and opportunistic.

*5.1.1 Explicit Reflection.* Section 4 showed how Kaleidoscope enabled explicit reflection on process, both through direct assignments like the extra credit Reflection Assignment, and when putting together communicative documents like the final portfolios. Explicit reflection depends on specific time and context, where practitioners can enter a reflective rather than creative mindset: Lin et al. discuss how computer tools that deliberately bring a student from one learning environment to another can support explicit reflection [34]; like UID's Reflection Extra Credit, Roldan et al. used explicit reflection assignments at key points in the course [46].

Having a concrete medium to ground explicit reflection is important. Trying to reflect without grounding artifacts is susceptible to memory errors, such as focusing only on particularly memorable instances, or missing subtle details [46]. Our findings showed two primary design decisions that contributed to Kaleidoscope acting as a useful medium for design history: centralizing the history of design activities from multiple sources into a single location, and

presenting these traces of history in a visual way that showcased multiple artifacts at once. Different types of artifacts can be used to ground reflection: Roldan et al. explore video [46], and Fleck et al. discuss how reflecting on different mediums, such as records of events, audio recordings, or sensor data, allow returning to forgotten topics or seeing from new points of view [20]. Kaleidoscope's approach could be combined with other mediums to expand opportunities for sensemaking.

*5.1.2 Opportunistic Reflection.* In addition to engaging with their Kaleidoscope histories to perform intentional metacognition on process, students also used Kaleidoscope to support their design work, such as referencing old iterations of artifacts, catching up on progress from team members, or sharing feedback. Kaleidoscope's display of the project history allowed these practical tasks to become moments of *opportunistic reflection*. Without setting aside time for explicit reflection, students were able to see how ideas evolved, identify the benefits of iteration, and recognize their own learning accomplishments through the progress they had made. In the context of expert practitioners, Sterman et al. showed that ambient display of history and revisiting artifacts opportunistically supports reflection on personal process and creative identity that can direct and inspire future work [51]. Kaleidoscope enabled opportunistic reflection that was otherwise difficult or impossible with existing tools, by surfacing older work with newer work, and presenting a view of the entire history as a starting point for design tasks. In our remote semester, digital spaces were the only shared spaces for teams; yet even during in-person semesters, courses like UID do not have permanent physical studio spaces for undergraduate teams. For courses where studio critiques and project workspaces are ephemeral due to constraints of classroom space and resources, the digital studio may continue to provide opportunistic reflection.

*Kaleidoscope's process documentation created a concrete medium for explicit and opportunistic reflection; concrete representations may benefit HCI design courses where students reflect on abstract learning goals like "design process".*

## 5.2 Challenges to Integrating Documentation with the Design Process

Our second guiding research question asked *How can a documentation tool directly support students' design process in collaborative interaction design projects?* Besides enabling reflection, a successful documentation tool should help students do good work and learn process by doing. Kaleidoscope directly supported students in certain parts of their design processes, especially in tasks related directly to documentation: referencing old artifacts, group collaboration, and giving and receiving feedback. In this section, we discuss three challenges Kaleidoscope encountered in supporting design work.

*5.2.1 Overwhelm and Sprawl.* One challenge to effective process support was that students felt overwhelmed by the quantity and clutter of artifacts in their studios (Sec. 4.4). Chen et al. identified a similar theme in their probes of documentation behaviors in a design course, where "sprawl" made it difficult for students to find artifacts and records they needed among the vast quantity of documentation they had created [13]; Dalsgaard et al. identify choosing what to document and at what level of detail as a key challenge even for experts [17]. A first reaction to solving the problem of overwhelm might be to organize the artifacts better; however choosing which artifacts to document is a more foundational issue that contributes to sprawl. Chen et al. discuss this as the "Cartographer's Dilemma" [13]. Much like Borges's point-for-point map [7], we saw this dilemma among our students as they tried to identify what changes would matter to them later (Sec. 4.1), and what would simply clutter the studio. Both too much and too little documentation resulted in frustration. Sterman et al. explore a similar issue in version control systems in creative practices, identifying low-fidelity versioning as one solution to the Cartographer's Dilemma when practitioners prioritize flexibility and spontaneity [51]. In the cases of lower-fidelity documentation, the choice to exclude detail is deliberate and carefully aligned with the practitioners' context. Simply capturing less detail does not solve overwhelm and sprawl. Identifying important changes and managing iterations is an important skill for students to learn; a documentation tool could help scaffold students towards recognizing and practicing this skill.

*5.2.2 Mindsets and 'Mode Switching'.* Besides the challenges of too many artifacts, some students also struggled with documenting enough artifacts. Section 4.1 explored how the labor of documentation disrupted creation, breaking students' flow [15]. To avoid breaking flow, students sacrificed documentation. The labor of creating documentation is a well-explored challenge: da Rocha et al. discuss the tension between interrupting flow to create documentation, and the necessity to document immediately after creation [23]; Dalsgaard et al. discuss how even in research, the time and effort needed to document can be at odds with design flow [17].

But viewing documentation purely as a negative interruption may not be the whole story. In prior work, we discuss the strategy of 'mode switching' in expert process, where practitioners move between tools and tasks to intentionally alter their mindsets and focus [40]. Several of Kaleidoscope's design choices position it as a tool for reflection, but not creation: it is a standalone documentation tool, where artifacts can be only minimally edited but are easily viewable in relation to each other. Therefore students are forced to 'mode switch' as they moved between their creation tools (Figma, sketching, text editors, etc.) and their documentation tool (Kaleidoscope). In the student experiences reported in Section 4.1, we see using Kaleidoscope for documentation can either be disruptive – when students are in a flow state of creating – or beneficial – when it allows students to step back and curate or revisit their documentation, either through portfolios, feedback, or reflection.

In expert practice, mode switching is defined as an intentional, productive strategy. To maintain productive mode switching during *curation* and *reflection* stages, a tool like Kaleidoscope should provide a focused, standalone view into history separate from creation tools. This mode supports higher-effort curation tasks and explicit reflection. Yet to reduce unproductive context switching during *creation*, a tool like Kaleidoscope might benefit from low-effort, low-interruption recording of artifacts; if reflection occurs, it should be opportunistic rather than explicit.

In 'mode switching', different mindsets are often enabled by different tools. In the next section, we consider a possible way to

move towards productive mode switching for student documentation and reflection using ecosystems of tools, in combination with a discussion of Kaleidoscope's relationship to the learning goals of design process and teamwork.

*5.2.3 Addressing Overwhelm and Mode Switching: Integrating with an Ecosystem of Tools.* Students work on their design projects in many other tools; in UID, common tools included Figma, GitHub, physical paper, GoogleDocs, GoogleSlides, and more. Some of these tools capture their own histories internally, but do not make these histories accessible in a way that supports reflection [51]. Kaleidoscope was designed as another stand-alone web platform alongside these tools. Kaleidoscope integrates with some of the tools that students use in the course: importing Figma projects from a URL with a live thumbnail, and automatically importing GitHub commits from linked projects, but the primary interaction paradigm is to manually upload individual artifacts to the platform. One effect of this design choice is that users must go to Kaleidoscope specifically to record an artifact. This forces the user to *mode switch*, entering a documentation tool and mindset, and requires an active choice to create a record of a moment in the design history.

In order to address the paired issues of overwhelm and breaking flow through unwanted mode switching, we consider here how to integrate Kaleidoscope more effectively into the broader ecosystem of tools. One envisionment might be to rethink Kaleidoscope as a wrapper around the tools in which students do the work of design and creation. By leveraging the internal histories of tools like Figma or GoogleDocs, a reflective documentation tool could pull in artifacts that reflect particular points of change automatically, much as we did with GitHub commits. Students would not have to leave their design tools to make an artifact; perhaps they could even mark or annotate particular key artifacts from the tool in which they were created. Small changes would be kept within the tool's history, while important changes could be surfaced in Kaleidoscope, combating sprawl and overwhelm while still tracking the full history. Artifacts could be promoted to Kaleidoscope if they turn out to be important, and demoted to the original tool if the team decides they are insignificant. In such a design, Kaleidoscope would link back to the source tool from each artifact, allowing easy transitions between tools for creation and tools for reflection in order to continue to enable opportunistic reflection during design activities such as catching up on teammates' progress or revisiting old iterations. Explicit reflection would be supported within Kaleidoscope, where drawing multimedia histories together from multiple tools would continue to enable reflection across the entire design process in a visual manner. Integration with creation tools may also address privacy and visibility, allowing teammates to capture histories of in-progress work in the source tool without feeling that it has been made public or permanent to the broader team until they are ready.

The histories currently supported by individual digital tools are comprehensive changelogs, but are siloed and intended more for error reversion than for reflection or other aspects of process [51]. From our experience with a standalone version of Kaleidoscope, we have seen the benefits of history tools that bring together multiple mediums from the design process, and present them in an accessible format for reflection. The next iteration of reflective documentation tools may combine the benefits of both these approaches to reduce overwhelm and better support reflection.

*Documentation tools for reflection may benefit from integration with the broader ecosystem of tools, such the labor of documentation does not interrupt a student's creative flow, and the labor of curation integrates with reflection.*

## 5.3 Incentives and Motivations for Documentation

Chen et al. proposed an open question: *"To what degree do these documentation practices carry on into professional practice in creative fields once the academic requirements of documentation processes are removed?"* [13] Our third research question addressed the inverse question: *How can strategies of expert process be incorporated into tools for student learning?* In this discussion of Kaleidoscope's deployment, we must also ask *To what degree is it* appropriate *for documentation practices from professional practice to be brought into the academic context?* The design principles that guided Kaleidoscope drew strongly from expert practice [29, 40, 47, 51], yet the extrinsic motivators of the academic environment created challenges for applying intrinsically motivated expert practice in the academic environment.

In a course setting like UID, some motivations for documentation overlap with expert practice, while others are specific to the educational context. Documentation can contribute to internal project process: like experts, students document to communicate with their teammates, to structure their own workflows and design cycles, and to perform metacognitive reflection. Documentation can also be for external consumption: while professionals might document for clients or public dissemination, students must document in order to submit assignments, receive grades, or create final presentations and portfolios. Ideally these goals would balance in the learning context to support both learning goals of external communication and internal process. However, this research revealed multiple ways these motivations can work against each other.

Amabile has shown dampening effects of extrinsic motivation on creativity [5]. In the academic context of our institution, as in others, students are constantly under pressure to complete the next assignment or take the next class, with little institutional support for reflection or returning to old work. This leads to a gap between process in courses and process in expert or personal practice. For example, one student expressed different mindsets around maintaining history between personal and course projects:

> For my personal projects [and] research I'm a little bit more cognizant of keeping things organized... so that if I'm stuck or if I don't know where to go in my research, I can just go back into those archives and try to spark something or remember what I did. But for group projects because it's more of like getting them [done] quick, and it sometimes may not apply to my own interests, I take less care to keep those things organized. *(S117 - Midsemester Interview)*

In Section 4.5, we discussed students' perceptions of Kaleidoscope as a submission platform, instead of a tool for design. Chen et al. note a similar effect, where the implicit and explicit expectations of the course setting shaped students' behaviors and perceptions of

documentation as primarily an external requirement for communicating with instructors and peers [13]. With Kaleidoscope, students often became aware of the benefits of documentation as a medium for reflection only later in the course, when they had to manage a larger project, perform explicit reflection, and communicate with teammates and external audiences (Sec. 4.1, 4.5). Students did benefit from expert design strategies, such as opportunistic reflection, identifying progress, and enhancing collaborative discussion, which suggests that there is value in integrating documentation strategies from expert practice into educational tools. But tools alone cannot change behavior without support from the broader course structure and environment.

How might we restructure the incentives and implicit and explicit expectations of the academic environment to help students to practice the multifaceted purposes of documentation? One small step might be *making metacognition an explicit learning goal within the course to align student effort with extrinsic motivators, leading to earlier buy-in from students on the value of documentation and reflection.*

## 6 LIMITATIONS

The development and deployment of Kaleidoscope in a course over four months allowed us to collect real-world user data and learn from student needs as we iteratively designed the tool. However, the time pressures of the semester and the requirement to support particular course needs also limited the features we could release, and meant students encountered bugs with the system. This made interactions with Kaleidoscope less fluid than with stable commercial tools. Among the features we could not prioritize were techniques for interactive critique. Critique is essential to a studio course like UID, and while Kaleidoscope artifacts could be used in a critique session, we did not implement specific features beyond basic feedback interactions. Both studio critique and feedback are complex domains of their own; the extensive research in these areas might be combined with our work on documentation fruitfully in the future. Similarly, implementation of logging was constrained by the challenges of parallel development and deployment. Logging was added to features at different times across the semester primarily to support system debugging and resolve student issues. Therefore we are unable to analyze quantitative metrics for interaction logs. Such data sources may provide additional insight in the future, but were out of scope for this research.

Kaleidoscope was designed and deployed specifically for UID, an interaction design course, and our design decisions are inextricable from that context. For example, Kaleidoscope primarily supports visual and interaction design. Physical artifacts are incorporated through photographs or other digital representations, however other forms of design which focus more fully on other types of artifacts or processes might require alternate design decisions. Similarly, we focused on individual students, groups of students, and instructors as key stakeholders in privacy and collaboration considerations in UID. However, projects in other design courses might include sensitive data, such as interview data or photographs, or materials generated during co-design sessions. Expanding Kaleidoscope to support these aspects of the design process would require additional consideration of participant privacy in data access and representation.

## 7 FUTURE WORK

Future work might explore how documentation tools like Kaleidoscope can more explicitly support reflection on process, for example, creating visualizations of team interaction and artifact creation patterns, or integrating reflection prompts in the tool. Kaleidoscope drew from the strengths of existing tools by interfacing with Figma, GitHub, and YouTube, but also competed with these tools for student time, effort, and attention; we might consider how to lower the amount of effort needed to document work, either by further integration with existing tools, or pursuing documentation layers within an ecosystem of tools rather than as separate platforms. While Kaleidoscope was deployed during a fully remote semester, it may be fruitful to explore how to document and reveal process during hybrid or in-person courses as well, integrating a tool like Kaleidoscope into in-person activities, or pursuing hybrid-specific tool designs. Future work should also address student buy-in to reflection and metacogntion; we might investigate when it is appropriate to introduce discussions of meta-concepts around process to students, and how to align the incentive structures of the educational context with reflection. Tool design can only go so far in the educational context; assessments, motivation, and learning goals must all be aligned to support desired behaviors.

## 8 CONCLUSION

In this paper, we presented Kaleidoscope, a documentation system for design process. We deployed Kaleidoscope in an upper-level undergraduate user interface design course during a remote semester. Kaleidoscope displays artifacts generated during the design process in a virtual studio space, providing a shared repository for project teams to collect their work, document and annotate their progress, and receive feedback from peers and instructors. We report data from a variety of surveys, critique sessions, discussions, and interviews with students and course staff to understand how a documentation tool like Kaleidoscope can support collaboration, metacognition, making progress visible, high-level views of project histories, and personalization of a remote studio environment. We discuss successes and challenges encountered by students and researchers, and how these insights might support HCI educators building tools for teaching design process. We envision the lessons learned from Kaleidoscope may support a future of design tools which holistically understand the design process wherever it happens, support student learning, sharing, and metacognition, and makes creative process visible for discussion, critique, and intentional modification.

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